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A COMPARISON OF AIR FORCE DATA SYSTEMS

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This report evaluates the effectiveness and cost of two alternative Air Force maintenance information systems: CAMS/REMIS and TICARRS. The evaluation considers six dimensions of effectiveness: functionality, scope, operating characteristics, data accuracy and completeness, adaptability, and logistics and operational effectiveness. Each system was found to have shortcomings. CAMS/REMIS suffers from problems in availability, responsiveness, and data integrity, and TICARRS is limited in functionality and scope. IDA considers two alternatives, each one based on one of the systems supporting the entire Air Force. A set of enhancements needed to make the two systems roughly equivalent is provided, along with their costs. The cost analysis includes estimates of the nonrecurring costs to address the system limitations and the recurring costs in system operations and maintenance from FY 1994 through FY 2003. The TICARRS-based alternative is found to be superior in effectiveness but must be expanded in scope and functionality if it is to become the Air Force's standard system. The estimated costs for the TICARRS alternative over the ten-year period are approximately $100 million less (in terms of present value) than the costs for the CAMS/REMIS alternative.

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PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Assistant Secretary of Defense (Production and Logistics) under a task entitled "Comparison of CAMS/REMIS and TICARRS." This paper serves as the final report on IDA's evaluation of the costs and operational effectiveness of two automated Air Force systems for maintenance information. One of the systems combines the Core Automated Maintenance System (CAMS) and the Reliability and Maintainability Information System (REMIS). The other is called the Tactical Interim CAMS and REMIS Reporting System (TICARRS).

This paper was reviewed within IDA by Bruce N. Angier, Herbert R. Brown, and James L. Wilson. Before this paper was released in its final version, the Office of the Secretary of Defense asked interested parties both inside and outside the government to review it and send their comments to IDA. These comments, along with IDA's responses to them, are contained in IDA Document, D-1400, "Comments on IDA Paper P-2863, 'A Comparison of Air Force Data Systems.'"

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EXECUTIVE SUMMARY

This paper compares the costs and operational effectiveness of two automated systems for collecting and providing maintenance and related information for the Air Force. One of these systems (CAMS/REMIS) combines the Core Automated Maintenance System (CAMS) and the Reliability and Maintainability Information System (REMIS). The other is the Tactical Interim CAMS and REMIS Reporting System (TICARRS).

CONCLUSIONS

In IDA's judgment, an alternative based on implementation of TICARRS provides at least as great effectiveness with less risk and less cost than CAMS/REMIS. In terms of effectiveness, CAMS/REMIS now suffers from problems with availability, responsiveness, and data integrity. TICARRS is currently missing some important elements of functionality and cannot support as many systems and kinds of equipment as can CAMS/REMIS. In our cost analysis, we included the cost of additional work needed to overcome the shortcomings of both systems. We remain very uncertain, however, that the data integrity problems of CAMS/REMIS can be fully overcome. Not only have these problems been persistent, but the CAMS/REMIS architecture works against their simple resolution.

Assuming a four-year phase-in period, we estimated that the Air Force could save $100 million in present value terms over the next ten years by choosing a TICARRS-based system. This is 18 percent of what we estimated it would cost to operate a CAMS/REMIS-based system over that period.

METHOD OF EVALUATION

We evaluated the operational effectiveness of CAMS/REMIS and TICARRS as they exist today. The effectiveness of the systems was compared along six dimensions: system functionality (what they do), scope (for what systems and equipment), operating characteristics (their availability, responsiveness, and ease of use), data accuracy and completeness, adaptability, and logistics and operational effectiveness (measured by mean time between failures, maintenance man-hours per flying hour, mission-capable rates). Limitations of the systems were identified through a review of documentation and extensive

discussions with users at all levels as well as system developers. In addition, IDA was able to use the Operational Assessment of TICARRS that took place at Seymour Johnson Air Force Base (AFB) during the spring of 1993 to better understand its strengths and shortcomings. To the extent possible, steps required to overcome the limitations of each system were specified and cost estimates developed.

The ten-year costs of the systems, modified as needed to improve and roughly equalize their effectiveness, were then compared. A ten-year time period was used, because it seems likely that newer information system technology should displace whatever system is chosen in about ten years.

The study evaluates two alternatives for the Air Force maintenance information system:

- Alternative 1: an enhanced version of CAMS/REMIS that incorporates improvements that are either under way, planned, or needed in the near future, and
- Alternative 2: an enhanced version of TICARRS that is expanded in function and scope to allow it to replace CAMS/REMIS.

OPERATIONAL EFFECTIVENESS OF THE CURRENT SYSTEMS

We found that CAMS/REMIS now handles a greater number of weapon systems and other types of equipment. It also has several important functions that are missing from TICARRS. However, we also found that TICARRS operates better and provides more accurate and complete data.

Table S-1 summarizes IDA's findings regarding the effectiveness of CAMS/REMIS and TICARRS as they exist today.

Table S-1. Comparison of the Effectiveness of CAMS/REMIS and TICARRS

Dimension of Effectiveness	Conclusion
Functionality	Greater for CAMS/REMIS
Scope	Greater for CAMS/REMIS
Operating characteristics	
Availability	Better for TICARRS
Responsiveness	Better for TICARRS
Ease of use	Equal at wing level, TICARRS better elsewhere
Data accuracy and completeness	Better for TICARRS
Adaptability	TICARRS better in short-term; little long-term difference
Logistics and operational effectiveness	No difference found

Functionality

CAMS/REMIS was found to have greater functionality than TICARRS, although there are some functions for which TICARRS is unique (e.g., block number tracking). Among the more important functions included in CAMS/REMIS but not in TICARRS are: interfaces with the Standard Base Supply System and the Comprehensive Engine Management System, and handling of personnel and training management and production scheduling and management.

Scope

CAMS/REMIS was found to support far more aircraft and other products (communications-electronics equipment, aerospace ground equipment, etc.) than does TICARRS. If TICARRS were to replace CAMS/REMIS, it would have to be modified to address more than 40 additional aircraft types and 1,700 types of communications and electronic equipment.

Operating Characteristics

Overall, TICARRS was found to have substantially better operating characteristics than CAMS/REMIS. These are briefly described in the following paragraphs.

Regarding system performance parameters, TICARRS and REMIS were found to provide much higher levels of availability than CAMS. TICARRS and REMIS both have had less than one percent of unscheduled downtime. CAMS has been unable to approach its target of 95 percent availability at the vast majority of bases.

TICARRS was found to have a better response time, particularly compared to REMIS. Some evidence indicated that TICARRS was able to produce standard reports in less than 30 minutes, while REMIS averaged 2.4 hours. Ad hoc REMIS reports took an average of 7.5 hours and in some cases up to 36 hours.

Regarding ease of use, neither system was found to be convincingly superior at the wing level. Except for some users at depots, other users above the wing level (Major Commands, weapon system System Program Offices, and contractors) emphasized their problems with REMIS and showed a preference for TICARRS when they were familiar with it.

Data Accuracy and Completeness

Where comparisons were possible, TICARRS was shown to have more complete and accurate data. There have been widespread, persistent failures in REMIS receiving the data it is supposed to get from CAMS. In addition, REMIS has been rejecting between 8 and 11 percent of the aircraft-related information (which represents one of the most critical types of equipment tracked in REMIS) it receives from CAMS because of data errors. For all equipment types, the total reject rate has ranged between 16 and 21 percent.

Adaptability

TICARRS is more adaptable in some ways. The Operational Assessment at Seymour Johnson showed that minor modifications to the system could be made quickly. TICARRS appears to be closer than CAMS to being able to deploy the kind of stand-alone system needed for wartime. However, neither system is likely to have a distinct advantage in aiding the transition to the next generation of maintenance information systems.

Logistics and Operational Effectiveness

We found no statistically significant relationships between the choice of maintenance information system and aircraft readiness and supportability (as measured by mission-capable rate, mean time between failures, and maintenance man-hours per flying hour). This is a short-run result and does not address the issue of using the information from these systems in longer-term efforts to identify bad actors, justify modifications, and so on.

EVALUATION OF COSTS

The total ten-year costs (FY 1994–FY 2003) of the systems modified as needed to improve their effectiveness are as follows (millions of FY 1994 dollars):

- CAMS/REMIS: $645.63
  - CAMS: $502.93
  - REMIS: $142.70
- TICARRS: $326.07

The two sections that follow explain: (1) the factors that drive those costs and (2) the cost of choosing one system as the Air Force-wide maintenance information system. The latter includes the cost of operating both systems until the chosen system has achieved full operational capability.

Cost Drivers

The cost differences that result from our comparison of CAMS/REMIS and TICARRS can be understood by identifying and evaluating the cost drivers for the information systems. The following factors greatly affect costs in maintenance information systems:

- volume of application software (developed, maintained) and size and complexity of the data base,
- computer operations,
- user support (both on and off-site), and
- communications.

Table S-2 shows representative annual recurring costs for CAMS, REMIS, and TICARRS that can be attributed to the four major cost factors.

Table S-2. Comparison of Recurring Annual Costs Across Systems

	Cost in Millions of Dollars			
	CAMS/REMIS			
Major Factors	CAMS	REMIS	Total	TICARRS
Software/Data Base	$3.5	$5.6	$9.1	$5.7
Computer Operations	$10.1	$2.4	$12.5	$4.0
User Support	$18.4	$1.1	$19.5	$8.1
Communications	$13.5	$0.2	$13.7	$13.8

The table shows that CAMS/REMIS costs more than TICARRS in three of the four categories. For volume of software, TICARRS has substantially fewer programmer-generated and maintained lines of code relative to CAMS/REMIS. For computer operations and user support, a central data base architecture system such as TICARRS takes much less effort to operate and maintain than the base-level replicated system of CAMS. Communications costs are roughly equal.

Costs of Alternatives

Table S-3 shows a cost comparison between the two alternatives we evaluated. Alternative 1 is an enhanced version of CAMS/REMIS. Alternative 2 is an expansion of the functionality and scope of TICARRS. For Alternative 2, we assumed the transition to TICARRS would take four years. The "Alternative 2 With Five-Year Transition" column represents an excursion from Alternative 2 with a one-year delay in TICARRS due to lengthy acquisition procedures.

Table S-3. Total Cost Comparison Between Alternatives

System	Cost in Millions of FY 1994 Dollars		
	Alternative 1 (CAMS/REMIS-based)	Alternative 2 (TICARRS-based)	Alternative 2 With Five-Year Transition
CAMS	$502.93	$154.98	$203.45
REMIS	$142.70	$48.00	$59.71
TICARRS	$16.91	$326.07	$293.58
Total	$662.52	$529.04	$556.73
Total (Present Value)	$562.25	$462.05	$485.45
Savings		$133.48	$105.79
Savings (Present Value)		$100.20	$76.80

Alternative 1: An Enhanced Version of CAMS/REMIS

Alternative 1 is CAMS/REMIS enhanced to improve its operating characteristics. Under this alternative, we assumed that TICARRS continues for 18 months, until shortly after REMIS is fully operational. We estimated that this alternative would cost $663 million (in FY 94 dollars) over the next ten years ($562 million when future costs are discounted). The major cost drivers are user support at the bases and computer operations.

Alternative 2: An Enhanced Version of TICARRS

For this alternative, we assumed that the functionality of TICARRS can be expanded to match that of CAMS/REMIS by the end of FY 1995, and that CAMS/REMIS would continue to be used while TICARRS is expanding. Adding the required functionality is not, in our judgment, a major cost driver. The major cost drivers for expanding TICARRS are in initializing the data base for each new weapon system, acquiring additional hardware to handle the additional work load, and changing the individual Air Force units from CAMS to TICARRS.

The various requirements of a formal MAISRC acquisition process result in TICARRS being fielded in place of CAMS/REMIS no earlier than the fourth quarter of FY 1997. An alternative based on TICARRS was estimated to have a ten-year cost of $529 million ($462 million when discounted). In present value terms, Alternative 2 would be $100 million cheaper, a savings of 18 percent relative to Alternative 1.

If the policies and procedures of the acquisition process require more time to change over to a TICARRS-based system (i.e., five years), the present value of total costs to implement TICARRS would be $485.5 million, compared with $562.3 million for the CAMS/REMIS alternative (Alternative 1). This represents a savings of $77 million or 14 percent.

RISKS FOR EACH ALTERNATIVE

Given the resources we estimated as necessary for each system, we assessed the technical risk involved in the enhancements. We judged overall risk to be low to medium for the CAMS/REMIS alternative and low for the TICARRS alternative.

Both CAMS and REMIS have efforts under way to address their shortcomings. Our cost estimates included additional expenditures to further improve the performance of CAMS/REMIS. Nevertheless, some aspects of the design and history of CAMS/REMIS cast doubt on the ability of that system to significantly improve performance. The move to Regional Processing Centers will not, by itself, improve the availability of CAMS. Improvements to availability depend on: (1) improved software quality and (2) the provision of the appropriate mix of skilled personnel (data base managers) at the bases. Moreover, CAMS will continue to be operated in an environment in which it must compete with other base-level applications for computer system resources. System responsiveness is likely to continue to suffer in the future.

It should be possible to adequately improve the responsiveness of REMIS. However, we believe that this will require substantially greater resources than are currently being applied.

The biggest potential problem involves the completeness and accuracy of CAMS and REMIS data. The fielding of the Generic Configuration Status Accounting System (GCSAS) may improve the situation, but the complex nature of the interface between the two systems, and the data rejects that may still result, could yield data that are not accurate enough to meet some of the Air Force's requirements. It is difficult enough to enforce data integrity within one system. CAMS/REMIS may be programmatically one system but they are, in reality, two systems, with different record formats, different architectures and different edits.

While it appears to be possible to expand TICARRS in functionality and scope to perform the tasks that CAMS/REMIS currently supports, a major expansion is not without risks. In our analysis of alternative systems, we included the cost of expanding TICARRS and changing over all Air Force units from CAMS to TICARRS. Even though limitations in scope and functionality are weaknesses of TICARRS today, the flexibility of the system's architecture supports optimism about TICARRS's ability to be expanded as needed.

I. INTRODUCTION

A. BACKGROUND

This paper compares the costs and operational effectiveness of two automated systems for collecting and providing maintenance and related information to the Air Force. One of these systems (CAMS/REMIS) combines the Core Automated Maintenance System (CAMS) and the Reliability and Maintainability Information System (REMIS). The other is the Tactical Interim CAMS and REMIS Reporting System (TICARRS).

The CAMS segment of CAMS/REMIS is the standard Air Force base-level maintenance information system. Its development began in the early 1980s, and as of December 1992 it was installed at 107 Air Force bases. It supports all Air Force product groups (aircraft, engines, missiles, support equipment, test equipment, etc.) and functions within maintenance operations at the base level, using the Standard Base Level Computer (SBLC) system. It also supports NATO's Airborne Warning and Control System and the Royal Netherlands Air Force.

The REMIS segment of CAMS/REMIS is the Air Force's central data base for reliability and maintainability (R&M) data. Its objective is to be the repository for all Air Force R&M information and to support system readiness and sustainability. REMIS integrates base-level data provided by CAMS.

TICARRS was derived from the Centralized Data System (CDS) developed for the F-16. It is now being used to help support F-16s and many F-15s. A version of TICARRS, called Smart Data System (SDS), was also used to support the F-117A until that aircraft switched to CAMS. TICARRS uses a central data base architecture. TICARRS used to receive direct input of base-level data. Currently, base-level data are supplied to TICARRS by CAMS.

The fiscal 1992 Defense Appropriations Conference Report expressed concern about the ability of the CAMS/REMIS systems to provide timely, accurate, and comprehensive data to Air Force system managers. The General Accounting Office (GAO) was directed to make an independent assessment of these systems. The GAO found that several base-level studies of CAMS indicated that problems with system performance and

data accuracy persisted. The GAO also found that REMIS had serious software deficiencies, many of them leading to major errors.

The Conference Report on the 1993 Department of Defense (DoD) Appropriations Bill supported the continued operations and enhancements of CAMS/REMIS and TICARRS and directed the DoD to have the Institute for Defense Analyses (IDA) perform an independent analysis of the systems. This paper is the outcome of that analysis.

B. PURPOSE

The purpose of the IDA analysis was to compare the costs and benefits of the two information systems—CAMS/REMIS and TICARRS. This comparison was conducted within the framework of Air Force requirements for information about logistics functions such as system and equipment management, maintenance, and configuration.

In part to respond to congressional interest, the Air Force recently undertook an Operational Assessment of TICARRS 92 at the 4th (F-15E) Wing, located at Seymour Johnson Air Force Base. TICARRS 92 is the most up-to-date version of TICARRS. It is similar to the SDS. The Operational Assessment involved directly entering base-level data into the TICARRS data base and minimizing the use of CAMS within the wing for six weeks. Relevant wing personnel were trained in the direct use of TICARRS.

Analysis of the results of the Operational Assessment of TICARRS 92 was part of the study effort.

C. APPROACH

Our approach to the problem was to thoroughly evaluate the strengths, weaknesses, and differences in the capabilities of CAM/REMIS and TICARRS. Having made these evaluations, we defined two alternatives with essentially equal capabilities that meet Air Force requirements for a maintenance information system. One alternative is based on CAMS/REMIS and the other on TICARRS. The study provides an estimate of the recurring and nonrecurring costs of each alternative over a ten-year period.

D. OUTLINE

This paper contains eight chapters and six appendices. Chapter II contains an overview of CAMS, REMIS, and TICARRS. Descriptions of each system's functions, hardware and software configuration and management, and current status and future plans are provided.

In Chapter III, we explain some considerations that underpin the approach that was used to evaluate maintenance information systems. In addition to the future costs implied by a particular system, we considered six dimensions of effectiveness. They were:

- functionality (What does the system do and not do?),
- scope (What aircraft and kinds of equipment does it handle?),
- operating characteristics (How well does it function?),
- data accuracy and completeness (How good is the information it produces?),
- adaptability (How well could it accommodate changing environments and technologies?), and
- logistics and operational effectiveness. (How does it affect the performance of maintenance? How does it affect the ability of wings to meet their commitments?)

The sources of information used to analyze the alternative systems are reviewed in Chapter IV.

Chapter V contains our evaluation of CAMS/REMIS and TICARRS as they exist today. Five kinds of activity were drawn upon:

- extensive review of literature and documents dealing with CAMS, REMIS, and TICARRS;
- discussions with users;
- discussions with system developers and maintainers;
- analysis of information on the logistics and operational effectiveness of aircraft wings using CAMS/REMIS and TICARRS;
- analysis of information developed as part of the Operational Assessment of TICARRS 92. This analysis included examination of responses to survey questionnaires that IDA helped develop as part of the Operational Assessment team. It also incorporated data on the functional capabilities and shortcomings of TICARRS 92 developed during the Operational Assessment.

In Chapter VI, we describe two alternative configurations for the Air Force's maintenance information system. One is based on CAMS/REMIS, the other on TICARRS. The Air Force is implementing a major program to improve the operating characteristics of CAMS/REMIS, and we took the likely outcome of that program into account. Similarly, we accounted for the fact that both the functionality and the scope of TICARRS would have to be expanded for it to be able to effectively replace CAMS/REMIS.

The alternatives considered were:

- an enhanced version of CAMS/REMIS that incorporates improvements that are either under way or planned for the near future and
- an enhanced version of TICARRS 92 that is expanded in function and scope to allow it to perform all the tasks it must perform to replace CAMS/REMIS.

The characteristics of the systems embodied in the alternatives (hardware, software, and support) are specified in some detail, and the likely operating characteristics of the systems are described.

In Chapter VII, the estimated costs associated with the two alternative systems are presented.

Finally, Chapter VIII contains our conclusions.

The contents of the six appendices are as follows: Appendix A contains the results of an investigation of the relationship between bad-actor detection and data accuracy; Appendix B lists the literature reviewed for our evaluation; Appendix C contains the survey questionnaires used at Seymour Johnson; Appendix D describes our test of REMIS functionality and selected operating characteristics; Appendix E explains our vision of the future Air Force; and Appendix F describes an analysis of the effects of the systems on weapon system performances.

II. SYSTEM DESCRIPTIONS

This chapter contains thumbnail sketches of CAMS, REMIS, and TICARRS to give readers not completely familiar with them an introduction to the subject. Chapter V contains the detailed information about each system that served as the basis for the IDA assessment of system functionality and operation.

CAMS and REMIS combine to gather and provide maintenance information for the Air Force. Sometimes, we refer to them as a single information system, CAMS/REMIS. However, considering the extent to which they differ in system architecture, hardware, and management, they are better thought of as two systems that interact with each other. Our descriptions treat them as such.

A. CORE AUTOMATED MAINTENANCE SYSTEM (CAMS)

1. Functional Overview

CAMS is the standard Air Force *base-level* maintenance information system. It supports all aircraft, engines, trainers, support equipment, test equipment, missiles, munitions, and communications-electronic maintenance at the base level. CAMS originally incorporated and enhanced the functions of its precursors, the Maintenance Management Information Control System (MMICS) and the Maintenance Data Collection (MDC) system. It allows on-line information entry and retrieval from a data base that is integrated at the base level.

A number of the functions supported by MMICS and MDC were functionally enriched, converted to the CAMS environment, and released with the initial fielding of CAMS in 1985. The major functions provided in the initial fielding were as follows:

- Job Data Documentation (JDD). This subsystem replaced the MDC system by providing the maintenance community with a complete on-line capability to enter, store, and retrieve maintenance information.
- Training/Personnel. This subsystem is used to produce manning rosters, listings, and course codes. It links people to requirements and provides a training forecast capability.

- Inspection/Time Change. This subsystem tracks equipment and time change information, allows the development and use of job-flow packages to track items through the inspection cycle, establishes inspection/time change records for each piece of tracked equipment, and provides inspection/time change forecasts.
- Status and Inventory Reporting. This capability allows for the establishment of an initial inventory and provides automated equipment status updating, equipment status information, and analysis of equipment condition.
- Time Compliance Technical Order (TCTO). This is used for entry of TCTO information, reports of TCTO status changes, and inquiry of TCTO-related activities.
- Comprehensive Engine Management System (CEMS). This system provides data to the CEMS data base in the appropriate format.

Additional functions were added to CAMS over the period 1985–1992:

- Maintenance-Supply Interface. This subsystem, fielded in August 1990, automated the part-ordering process through an electronic interface with the Standard Base Supply System (SBSS).
- Automated Debriefing. This function, fielded in October 1988, provides automated air crew debriefing functions and automated generation of the Air Force Technical Order (AFTO) 781 series forms.
- Automated Scheduling and Status Inventory Reporting Systems. This function provides the mechanism to plan and schedule equipment use and maintenance on a monthly, weekly, or daily basis. It provides equipment status and location information and analyzes equipment condition. The automated scheduling function was fielded in August 1988. The status inventory reporting function was fielded in August 1992.
- Personnel Availability. This function, fielded in August 1992, automates information on current personnel availability and forecasts future availability.
- Automatic Test Equipment Reporting System (ATERS). This subsystem provides on-line access to a data base containing organization, equipment, status, and utilization data for assigned test equipment. It also keeps track of the capability of various test stations to test particular parts.
- Product Quality Deficiency Reporting Subsystem. This subsystem reports known or suspected deficiencies for equipment, weapon systems, or related components and records exhibit disposition instructions and data.
- REMIS Interfaces. This series of functional interfaces is designed to support REMIS.

2. System Configuration and Management

The software application functions for CAMS were developed and are currently maintained by personnel at the Standard Systems Center (SSC) at Gunter Annex to Maxwell Air Force Base (AFB), Montgomery, Alabama. The CAMS Program Office merged with the REMIS Program Office in 1991.

The CAMS programs collectively consist of 1.1 million unique source lines of code and are written in COBOL. The programs interface with the Unisys operating system, data base manager, and communications access method. CAMS uses a network-hierarchical data base with about 320 record types and over 300 sets.

The data base varies in size depending on the activity and equipment supported at the specific base. Typical size is in the range of 1.5 million to 2.0 million records.

CAMS operates on the Standard Base Level Computer (SBLC), which is a Unisys 2200/40x series, and shares that system with other base-level data-processing workload. CAMS operates at 109 active bases and supports 153 National Guard and Reserve sites, the Royal Netherlands Air Force, and NATO airborne warning and control aircraft units.

CAMS supports a variety of terminal types, including video display terminals, personal computers, terminal printers, and remote line printers, all in accordance with the SBLC architecture.

With CAMS, intra-base communications are provided by the communications configuration of the particular base. Generally, the configuration is a local area network, direct connected cables, or leased lines. Data transfers are handled under proprietary protocols (Unisys). Inter-base communications occur on the Defense Data Network using Transmission Control Protocols/Internet Protocols and the Automatic Digital Network.

3. Status and Plans

a. Status

CAMS achieved full operating capability in August 1992. The following functional capabilities originally included in the functional specifications have been eliminated or deferred until requirements are revalidated:

- the administrative/logistics module (not required),
- follow-on CEMS interface (deferred, now in work),
- quality assurance/quality control (deferred), and
- deployable CAMS (deferred).

b. Plans

The CAMS program management at Gunter AFB is directing its programming resources to responding to the problems users have identified with the system. A key development activity, referred to as "CAMS Optimization," incorporates repairs to software defects and adds help screens, simplified data-entry screens, more meaningful error messages, and the like. The plan calls for improvements to be available for installation at the base level in four quarterly increments between April 1993 and January 1994.

In addition, CAMS development personnel are continuing their work to support REMIS, including interfaces with the Generic Configuration Status Accounting System, which will not be fielded until after its Major Automated Information System Review Council (MAISRC) III.

The CAMS Program Office is investigating the possibility of having designated field representatives support CAMS users in the future. The services provided by these field representatives would be different than those provided by the current base-level data base managers. The representatives would be given training in maintenance operations (so that they can understand the use of the CAMS system for specific maintenance-related functions) in addition to expertise in CAMS systems operations. Their role would be to provide on-site support to CAMS users and to interact with CAMS developers to improve system functionality and performance.

CAMS development will be completed during 1993, and only enough technical personnel will be retained to meet operations and maintenance needs. It is expected that additional enhancement will need to be funded by the requesting user organization.

B. RELIABILITY AND MAINTAINABILITY INFORMATION SYSTEM (REMIS)

1. Functional Overview

REMIS is an integrated data base system that is meant to serve as a centralized source of inventory, status, utilization, configuration, and maintenance data for all Air Force weapon systems and support equipment. It provides a central data base architecture and processing environment that supports Air Force-wide reliability and maintainability analyses, as compared to CAMS, which contains maintenance data at the base level only.

Current maintenance processes and procedures require the use of twenty-three different information systems at Air Force Materiel Command (AFMC) Headquarters, the

Air Logistics Centers (ALCs), and the Major Commands (MAJCOMs). REMIS will replace most of these systems.

REMIS provides the capability to collect, edit, validate, process, store, and retrieve the data for aircraft, automated test equipment, communications-electronic equipment, missiles, and other items.

REMIS consists of three subsystems or modules:

- Equipment Inventory, Multiple Status and Utilization Reporting Subsystem (EIMSURS). EIMSURS contains the worldwide inventory, status, and utilization information for aircraft, missiles, trainers, communications-electronics equipment, and automated test equipment.
- Product Performance Subsystem (PPS). PPS is the central source for all Air Force equipment performance data derived from reportable maintenance information.
- Generic Configuration Status Accounting Subsystem (GCSAS). GCSAS will give the Air Force a single source of weapon system configuration data. Its major functions support the tracking of approved and actual configurations and Time Compliance Technical Orders.

2. System Configuration and Management

REMIS was developed by Litton Computer Services (LCS), which won a competitive contract in September 1986. The LCS team is responsible for the hardware, system and application software, data base, training, communications, maintenance, and integration support. REMIS consists of 736,000 COBOL source lines of code (data declarations and executable lines, excluding comments). REMIS uses Tandem VLX computers and system software, including the Tandem Guardian 90 operating system and the Tandem NonStop SQL data base manager. REMIS uses a centralized, integrated, relational data base with over 100 million records on line.

REMIS uses five regional transaction concentrator centers (Hill, Kelly, Robins, McClellan, and Tinker AFBs), four of which have two Tandem VLX processors and the fifth of which (Tinker) has five Tandem VLX processors. Each of the centers manages user log-on, authorization, local communication functions, and screen control. REMIS screen formats are stored at each of the concentrators to reduce transmission time from the central system.

The REMIS central system, located at AFMC Headquarters (Wright-Patterson), uses 20 Tandem VLX processors for production. Transactions are transmitted to and from the REMIS central system using 52-kilobit communication links.

REMIS terminals are personal computers, each connected to one of the regional concentrators using one of several possible types of connectivity methods (Ethernet, Direct Connect, dial-up, local area network, or Telnet).

3. Status and Plans

a. Status

The first component of REMIS, EIMSURS, was fielded in September 1990. The EIMSURS and PPS components have reached initial operating capability. Full operating capability is scheduled for June 1994.

b. Plans

There is an effort under way to improve the ad hoc report-generation system called REMISTALK. In addition, the possibility of improving system response time by more evenly distributing the processing load is being examined.

C. TACTICAL INTERIM CAMS AND REMIS REPORTING SYSTEM (TICARRS)

1. Functional Overview

TICARRS is a "fleet-wide" *centralized* data base that combined many (but not all) of the types of functions performed by CAMS and REMIS. It is a descendant of the Centralized Data System (CDS), which was first developed in 1979 under the sponsorship of the F-16 System Program Office. It was fielded in 1982 as a direct-entry and -retrieval information system for managing the maintenance of the F-16. Field representatives were added in 1983. During 1985, the Smart Data System (SDS) version of TICARRS was developed to support the F-117A. SDS continued to support the F-117A through Desert Shield and Desert Storm, after which it was also converted to direct organizational-level entry by CAMS as other systems had been in 1989.

TICARRS now receives organizational-level data from CAMS and provides weapon system performance information for the F-16, F-15E, and Multi-Stage Improvement Program F-15 aircraft to various users. These include personnel involved in operations, maintenance, support, and program management.

In its direct-entry form, known as TICARRS 92, TICARRS combines the 1987 version of TICARRS with SDS. TICARRS 92 includes the following functions:

- Equipment Inventory, Status, and Utilization. This function records the ownership and possession of equipment, as well as its mission performance capability and recent and historical utilization rate.
- Flight Scheduling. This subsystem provides for scheduling aircraft sorties, modifying and deleting them as appropriate.
- Support of the Maintenance Operations Control Center. TICARRS now includes an Automated Maintenance Operations Center, which tracks aircraft capability and other conditions critical to flight line and aircraft operations for generating sorties.
- Automated Debriefing. This function provides for direct computer entry of information on aircraft sorties and aircrew-reported discrepancies.
- Maintenance Job Generation and Tracking. This function generates the maintenance job orders to be performed and records the progress on these orders.
- Inspection/Time Change. Within this function, TICARRS schedules phase inspections as well as Time Change Items and records the work performed against these.
- Time Compliance Technical Orders (TCTOs). Within this function are entered the work to be done under each TCTO and the work performed.
- Configuration Management/Tracking. This function provides records of the items that are actually installed on a specific weapon system as well as those items formally authorized to be installed on that equipment.

2. System Configuration and Management

TICARRS 92 was developed and is maintained and operated for the Air Force by Dynamics Research Corporation (DRC). It incorporates a central data base architecture.

TICARRS operates from two Bull DPS90 processors. Communications processors consist of a Unisys DCP30 used over leased Sprint lines. A GCOS8 operating system and a TP8 transaction processor are used. The data base uses Integrated Data Storage II, is sized at 3.4 gigabits, and has about 22 million on-line records. The application software is in COBOL 74 (approximately 417 thousand unique lines of code), uses a productivity tool called Middleware, and has batch-input-batch-output. In its direct-entry form, TICARRS uses the base communications system for linkage to the leased lines that connect to the central data base.

3. Status and Future Plans

a. Status

TICARRS enhancements were halted in 1987 (with the version called TICARRS 87), but enhancements to SDS continued. In 1989, TICARRS stopped receiving organizational-level information directly and began being fed data from CAMS instead. However, it is still fed directly from depots, Product Quality Deficiency Report users, electronic mail users, and contractors. The continental United States (CONUS), is divided into six regions for support purposes. In addition, Pacific Air Force and U.S. Air Forces Europe are separate regions that use satellite communications to access the central data base. The TICARRS program has about 34 field representatives who provide support to users. Also, the CAMS/REMIS/TICARRS programs are now managed by a single program manager.

An Operational Assessment of TICARRS 92 was carried out at Seymour Johnson AFB for the 4th Wing (F-15E). The assessment focused on how well TICARRS can function as a replacement for CAMS. Wing personnel were trained in the use of TICARRS between 15 March and 26 March 1993. Starting on March 29, users' access to CAMS was restricted and they began entering data directly into TICARRS. This continued until 7 May, after which an evaluation was performed. IDA provided support to the assessment team, and has used assessment material in this study.

b. Plans

The Air Force has no plans to enhance TICARRS in any way, having chosen CAMS/REMIS as its standard system. DRC, however, has analyzed the work that would be needed to expand TICARRS to give it functionality and scope equivalent to CAMS/REMIS.

III. EVALUATION CONSIDERATIONS

Alternatives based on modifications of the current versions of CAMS/REMIS and TICARRS were evaluated on the basis of both effectiveness and cost.

A. DIMENSIONS OF EFFECTIVENESS

As noted in Chapter I, IDA addressed seven issues in examining the effectiveness of the alternative systems. They were functionality, scope, operating characteristics, data accuracy and completeness, adaptability, and logistics and operational effectiveness. Each of these is discussed briefly.

1. Functionality

The functionality of maintenance information systems, such as TICARRS and CAMS/REMIS, is the list of actions (or operations) that they perform or facilitate to help achieve the goals of maintenance organizations and other users. Describing those actions is not an easy task.[1] The actions are derived from the objectives of the organizations supported.

To develop a framework of functions an information system should provide, IDA took as a point of departure a 1990 study of the minimum maintenance management functions required in a deployed environment to sustain effective aircraft maintenance sortie production.[2] It became clear after a review of the TICARRS and CAMS/REMIS functional descriptions and other documents, as well as several field trips and interviews, that it would be necessary to break out in more detail some of the actions included in that study and add others to establish an appropriate framework for analyzing these systems. As a

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1 A reading of the functional descriptions of the two systems clearly reveals that the difference between them is a matter of word choice in some instances and a matter of substance in others.

2 Air Force Logistics Management Center Project LM902028, reported in Major Scott Taggart, Major John Wood, Captain John Renkas, Captain Jim Martin, Captain Keith Wynkoop, Captain Russell Ellwood, Chief Master Sergeant Benjamin Pate, and Mr. Carroll Widenhouse, "Maintenance Data Collection Review (On-Equipment Failure Data)," Report LM912082, Air Force Logistics Management Center, Gunter Annex to Maxwell Air Force Base, AL, October 1991.

result, IDA settled on a list of 17 major functional areas to compare CAMS/REMIS and TICARRS:

- equipment inventory,
- equipment status,
- equipment utilization,
- flight scheduling,
- support of the Maintenance Operations Center,
- debriefing,
- maintenance reporting/scheduling,
- maintenance supply system interface,
- comprehensive engine management,
- cannibalization tracking/management,
- configuration tracking/management for
  - aircraft and
  - engines,
- Time Compliance Technical Order (TCTO) management,
- personnel training/availability/scheduling,
- shop production planning/scheduling/control,
- mobilization planning,
- system deployability, and
- other features.

While this list is fairly extensive, the individual categories remain general and can accommodate a wide variety of specific functions within their boundaries.[3]

The CAMS/REMIS/TICARRS Program Management Office recently developed a comprehensive overview of required functionality that incorporates both the Air Force's stated requirements and the users' stated needs.[4] That overview was considered in the

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3 A successful comparison of information systems requires that these general categories be expanded into a list of relevant specific functions.

4 "System/Equipment Reliability and Maintainability (R&M) Enterprise Model," Century Technologies, December 1992.

development of the list of functional areas and provided a benchmark for our analysis of functionality.

2. Scope

CAMS/REMIS and TICARRS gather and manage information on different weapon systems and other equipment. Scope refers to the number of weapon systems or types of equipment about which an information system is designed to accept data. Currently, CAMS/REMIS has greater scope than TICARRS.

An important objective in our evaluation of TICARRS was to understand the difficulty (and expense) that would be involved in expanding the scope of TICARRS to be equivalent to that of CAMS. The Operational Assessment at Seymour Johnson provided some useful experience in that regard.

3. Operating Characteristics

The effectiveness of maintenance information systems extends beyond whether they are designed to handle the required tasks to how well they handle them. Indicators of the adequacy of a system's operating characteristics include:

- *system* availability—the amount of scheduled and unscheduled downtime;
- response time—the speed of system response to a key press or a simple query;
- turnaround time—the length of time from the start of a transaction to its conclusion; and
- ease of use—this has many aspects, including:
  - difficulty in learning to effectively use the system,
  - adequacy of training,
  - presence and type of help facilities,
  - presence of error checking, completeness of checking, and usefulness of error messages,
  - need for multiple data entry,
  - ease of obtaining reports, both standard and ad hoc, and
  - consistency of the user interface.

In Chapter V, we evaluate information system-based measures of effectiveness like these in our analyses of the competing systems.

4. Data Accuracy and Completeness

The principal purpose of maintenance information systems is to provide users with the data they need to do their jobs; however, the degree of data accuracy and completeness that is needed may vary across users and the supported weapon systems. We believe that there are substantial benefits to having accurate and complete maintenance data. These data are important to track weapon systems in their operations and to provide needed information on system performance for users who manage and repair the systems. If the data are not accurate, the costs to operate and support Air Force weapon systems will increase.

No system will yield perfectly accurate and complete data. When automated data are suspect, paper backup systems are sometimes used; however, they are expensive to maintain. Among the benefits of automated systems are lower cost, configuration control, error checking, and sharing of data across individuals or units. Paper systems are unlikely to be helpful to users who operate at a different level than the data are kept.

A consequence of incomplete or inaccurate data is that Air Force personnel make decisions based on data whose inaccuracies are unrecognized (uninformed decisions), or they recognize the inaccuracies and choose not to use the data, making decisions with little or no data at all. They may be unable to justify a course of action needed to support the weapon system. The costs and adverse consequences of such problems can be substantial.

How accurate and valid does the information need to be to support management and operational decisions in the Air Force? To examine this issue, we address the stated need for accurate and valid data in the documentation describing existing information systems and provide an independent, but subjective assessment as to how accurate the data need to be to support users of the information in various management and decision processes in the Air Force.

a. Requirements Stated in Functional Descriptions

The specific performance requirements for data accuracy and validity are presented in the functional descriptions for CAMS and REMIS. The TICARRS functional description does not have a requirement for data accuracy and validity. In CAMS the accuracy and validity requirements are: (1) mathematical calculations will be accurate to the fourth decimal place and (2) data will be 100 percent accurate within the limits of data edits for the data elements.

For REMIS the requirements are more extensive:

- Mathematical calculations—100 percent accurate to four positions right of the decimal point, when the number is expressed in scientific notation.
- Data—100 percent accurate for data elements edited by table look-up. Other data will be 100 percent accurate within the capability of the edits.
- Transmitted data—no less accurate than allowed by the Defense Data Network, which has a probability of an undetected error of 4.2×10^{-18}.
- Data validity—data will be validated before entry into the data base. At a minimum these checks will:
  - check data previously received to avoid duplication,
  - verify data elements not edited at the input source to ensure appropriate alphabetic or numeric data are contained in the required fields, and
  - verify the end-item serial number against the master inventory file to ensure valid serial number, equipment designator, and possessing organization is being reported.
- Statistical confidence—confidence inherent in the variability of data used in appropriate mathematical calculations and standard statistical analyses will be addressed. (Mean time between failures, mean time to repair, and other point estimates will have associated confidence bounds with a variety of statistical confidence levels, i.e., 90 percent, 95 percent, and 99 percent.)

b. Considerations of User Requirements

It is not apparent that these stated performance requirements were derived from a systematic consideration of the needs of various Air Force and industry activities for accurate and complete data. While the following review of users' requirements is not intended to be the definitive treatment of this subject, it does provide a perspective that needs to be considered in evaluating the effectiveness of the alternative maintenance management systems.

We conducted interviews with senior managers, middle managers, and system users in the logistics, acquisition, operational, and industrial communities to develop an understanding of data accuracy and validity requirements. We assessed requirements to the extent possible against the changing Air Force environment: the movement towards two-level maintenance, which places a premium on asset visibility; adoption of composite wings; emphasis on small, critical force structure elements (F-117 and B-2); and the increasing age of major portions of the force structure.

For some applications the data need to be more accurate than for others. To understand the consequences of data accuracy in one application, we investigated the relationship between the detection of bad-actor line replaceable units and data accuracy. The analysis develops a relationship between data accuracy and the time required to detect a bad actor. Time can be measured in temporal units if a specific maintenance cycle is assumed or in number of maintenance actions. The relationship between accuracy and time to detect a bad actor is negative. Better data get bad actors out of the system more quickly. Other studies indicate that the costs impacted include base labor, depot labor, transportation, and asset investments. Cost savings can be significant, especially for high cost items (avionics, engines). The details of the analysis are presented in Appendix A. Without a more complete investigation of the costs associated with different levels of accuracy, it is difficult to draw a final conclusion from the analysis; however, the analysis does indicate that a range of accuracy between 70 to 95 percent would probably be sufficient for bad-actor identification. For mission critical items (e.g., the Inertial Navigation System on the F-117), 90 to 95 percent accuracy would be needed, and for less critical items, a lower level of accuracy would probably be adequate.

From this review, IDA has developed an approach to data accuracy that relates functional activities to systems, users, specific types of critical information, and associated ranges of accuracy. These relationships, shown in Table III-1, represent a subjective assessment of the need for data accuracy from the users' perspectives. From the information presented in the table, it is clear that not all information needs to be available to the user at the same level of accuracy. For some applications, 70 percent data accuracy might be adequate to meet user requirements. However, even when 70 percent is sufficient, more accurate data might allow the user to define a problem better or select a corrective action more rapidly, resulting in reduced cost and improved operational effectiveness. Based on this subjective assessment, we believe that a maintenance data system will need to operate at a minimum level of data accuracy of about 90 percent.

For selected applications (safety of flight, mission critical equipment, and resource management), data accuracy requirements approach 100 percent. When a small number of functions require more accurate data than others, it may be easier to give additional management attention to those functions than to increase the level of accuracy in the entire data system. Equipment status and readiness data can be made highly accurate without imposing the same requirement on failure rate information. More extensive analysis of the costs and benefits of data accuracy could be very valuable.

Table III-1. Data Accuracy Requirements

Function	Systems	Principal Users	Critical Information	Accuracy Requirement	Why Needed?	Major Impact
Safety of flight	Engines Egress equipment Flight controls (fly-by-wire avionics)	Operating units Item/technical managers Depots	Current Configuration: Serially controlled items TCTOs Software version Maintenance events Time/operational change events	99 percent	Ensures weapon system maintenance activities provide for a safe system	Survivability
Mission critical equipment	Engines Selected avionics	Operating units System program offices Item/technical managers Contractors	Current Configuration: Serially controlled items TCTOs Software version Maintenance events System performance[a]	95 to 98 percent depending on mission essentiality of system or component	Provides increased probability of weapon system performing its wartime mission	Operational effectiveness
Predictive reliability and maintanaibility (R&M) analysis	Critical systems on high-value force structure elements	System program offices Item/technical managers Contractors Major commands	System performance[a]	90 to 98 percent	Provides predictive analysis to justify modification before operational capability of fleet is affected	Operational effectiveness Cost
Wartime readiness, flying-hour program, and weapon system possession management	All weapon systems	System program offices Item/technical managers Operating units Operating commands Depots Air staff	Flying hours/operating hours Mission capability rates Weapon system transfers (possession)	95 percent	Provides readiness assessments, resource management, and control of operating systems	Operational effectiveness Cost
R&M analysis, warranties, and maintenance activities, including production scheduling and configuration management	All weapon systems	System program office Item/technical managers Operating commands Operating units Depots Air staff Contractors	System performance[a]	70 to 95 percent, depending on mission essentiality of system or component	Used for logistics decisions on R&M modifications and software improvements, support of two-level maintenance, identification of bad actors, scheduling of work centers	Cost Operational effectiveness

[a] System performance includes the following types of data: mean time between failures, mean time between maintenance actions, maintenance man-hours per flying hour, mean time to repair, break rate, fix rate, cannot duplicate, re-test OK, bench check serviceable, narrative histories, current/approved configuration, work center scheduling, TCTO, and preventive maintenance status.

5. Adaptability

During the lifetime of the Air Force's tactical automated maintenance information system, the operating environment is likely to change in many significant ways. It is important to evaluate maintenance data systems with respect to their ability to adapt to these changing environments. Areas of change that must be considered are described in the following subsections.

a. Transition to War

Since it is the job of the Air Force to be ready to fight, it is necessary to analyze TICARRS and CAMS/REMIS in terms of their effectiveness in:

- peacetime conditions,
- mobilization conditions (e.g., Desert Shield), and
- wartime conditions.

Mobilization and wartime conditions may imply reduced access to information systems based in the continental United States (CONUS) and increased requirements for deployable communications or computer hardware.

b. Technology

Aircraft technology will change. In particular, the built-in ability of aircraft to diagnose the nature of equipment problems will probably improve substantially. The information system should be able to accept electronic information on failure modes and circumstances directly from the aircraft. Similarly, test equipment should be able to provide information directly to the information system.

Automated maintenance aids that use expert-system techniques may become widely available, replacing technical manuals. In some cases, these aids may be incorporated into test equipment. In either case, they would benefit from direct access to maintenance history data that should reside in the maintenance information system.

Computer technology will also improve. The automated maintenance information system should be one that can take advantage of these improvements without major effort or expense.

In addition, the need to interface with other data systems may change.

c. Maintenance Procedures

Air Force maintenance procedures may change in ways that make some kinds of information more important than they used to be. The possible move toward two-level maintenance and the associated requirement for asset visibility is an example of such a change.

The Air Force is currently testing the feasibility of moving towards a two-level maintenance concept. Two-level maintenance eliminates the intermediate-level, or back shop, repair process. If a technician cannot make the required repair at the flight line, the component is sent directly to the depot for repair, unless a quick back shop screening shows that it does not need repair. The objective of the two-level maintenance concept is to reduce costs (by eliminating much of the back shop). If transportation times are such that few additional assets are required in the pipeline, cost savings will be realized.

Coronet Deuce, the current Air Force two-level maintenance test, has shown that identification of bad actors, parts that continually exhibit the same failure but appear to be all right when tested, and parts that are believed to have failed but really have not are critical to the success of two-level maintenance. Information on the maintenance histories of parts is the only way to make the identification. The ability to use test equipment efficiently, facilitating rapid identification of bad actors and usable parts, should also improve the feasibility of two-level maintenance.

d. Organization of Combat Forces

The operational organization of the Air Force may change in ways that make some kinds of information more important than they used to be. The adoption of composite wings is an example of such a change.[5]

The Air Force is creating a number of composite wings, wings with single squadrons of different kinds of aircraft. The idea is to promote integrated operation and facilitate deployment of self-contained combat packages, including fighters, bombers, and tankers. This new structure is a departure from the traditional wing structure, which is made up of three squadrons of the same kind of aircraft.

The composite organization may pose challenges for maintenance and for maintenance information systems, particularly in the context of two-level maintenance.

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[5] Both two-level maintenance and composite wings involve performing more maintenance at locations other than the base where a part was found to fail. Easy access to fleet-wide maintenance history data may be more important under such circumstances.

With aircraft of a given type more widely dispersed, parts will probably spend less time, on average, at any one base. This could make base-specific repair histories for parts less valuable and easy access to fleet-wide information on part repair histories more valuable.

Our study considered the adaptability of both information systems to all these dimensions of change.

e. Organization of Weapon System Management

The Air Force has adopted Integrated Weapon System Management (IWSM), a concept that integrates cradle-to-grave management responsibility for a weapon system in one place. Under this concept, maintenance data should become more important early in the development process because greater attention will be paid to:

- Estimating operating and support (O&S) costs early in the process. O&S costs of similar systems are useful in this.
- Meeting reliability goals. Developers are given a reliability goal, for example, a target for mean time between failures or maintenance man-hours per flying hour. Maintenance records of similar existing systems help the government to set realistic goals for the new system.

Warranties presumably will become more common in this concept. Maintenance data systems are used to determine when contractors receive incentive payments or must provide free parts or pay penalties. With warranties, accuracy is critical.

Management of modifications may receive greater attention under IWSM. Such management requires that accurate maintenance data be fed back to contractors who are producing the system or parts of the system. Simple corrections of manufacturing or design defects could be made during the next production run, if flexible manufacturing fulfills its promise.

6. Logistics and Operational Effectiveness

Improvements in reliability and maintainability should generate improved mission-capable rates, sortie-generation rates, ground-abort rates, and air-abort rates. The existence and possible extent of these kinds of improvements are also examined in Chapter V.

A key presumption underlying the Air Force's stated requirement for an automated maintenance data collection system is that better information pays dividends in terms of better logistics. Thus, identifying problem parts and getting them out of the system should improve reliability. Accurate information on repair histories and failure modes should reduce repair times. Direct interaction between the maintenance and supply information

systems should reduce supply response times. Possible relationships between the choice of maintenance information system and indicators of logistics effectiveness are examined in Chapter V.

B. CATEGORIES OF COST

In considering the costs of the alternative systems, we used the following cost categories:

- Nonrecurring. The major cost elements in this category are hardware acquisition (including hardware to support system development), application software development, data base development, acquisition of communications equipment and commercial software, system integration and test, and user training.
- Recurring. The major cost elements in this category are computer operations, user support, and maintenance of the data base and the application software.

This cost structure is consistent with the much more detailed categorization of costs contained in the Automated Information System Cost Element Structure that is incorporated in the Draft Guidance on Automated Information Systems Cost/Benefit Analyses from the Office of the Director, Program Analysis and Evaluation.

Previous expenditures for both CAMS/REMIS and TICARRS were not counted in our evaluation of competing alternatives. The focus was on those portions of costs over which the Air Force still has decision power. However, information regarding past costs was used to assess the realism of estimates of future costs.

IV. SOURCES OF INFORMATION

In order to gain a thorough understanding of the characteristics, costs, strengths, and weaknesses of the information systems being evaluated, the IDA study team gathered information from various sources. Most of the information came from the following activities: review of the literature on the subject, discussions with both users and developers of the systems, collection of logistics and aircraft operations data, comparison of CAMS and TICARRS at Seymour Johnson AFB, and assessment of REMIS functionality and selected operating characteristics. These activities are described in the following sections.

A. REVIEW OF LITERATURE

IDA performed an extensive review of the literature on the systems being compared. The information was gathered from the following sources:

- the Office of the Secretary of Defense;
- the Program Management Office (PMO) for CAMS/REMIS and TICARRS;
- other Air Force activities, including Oklahoma City Air Logistics Center and Standard System Center at Gunter Air Force Base (AFB);
- information system contractors, including Dynamics Research Corporation and Litton Computer Systems;
- weapon system contractors, such as Lockheed Corporation; and
- general support contractors, such as Robbins-Gioia, Incorporated, Systems and Applied Sciences Corporation, Logistic Systems Architects, and Booz-Allen & Hamilton, Incorporated.

As literature was received, it was categorized according to type of material, information system covered, and date. A list of the documents that were obtained is contained in Appendix B.

The types of material were:

- information system documentation, including user's manuals and functional descriptions;
- program reviews and evaluations, including information compiled as part of the Major Automated Information System Review Council (MAISRC) and milestone review processes;

- cost estimates;
- briefings and presentations;
- correspondence.

Information was further categorized according to the system or systems it addresses: CAMS, REMIS, CAMS and REMIS, TICARRS, a comparison of TICARRS with CAMS and/or REMIS, and other material (such as discussions of future requirements for maintenance data).

B. DISCUSSIONS WITH USERS

Face-to-face discussions were vital to understanding how users interact with information systems. The IDA study team traveled widely to ensure development of this kind of understanding.

Users visited covered the Major Command (MAJCOM), program office, operational (wing and squadron), depot, and contractor levels. It was important to meet with users (and advocates) of both CAMS/REMIS and TICARRS. The activities visited are as follows:

- Air Combat Command Headquarters (and 1st Fighter Wing—F-15s), Langley AFB, Virginia;
- F-15, F-16, and F-22 program offices, Wright-Patterson AFB, Ohio;
- 4th Wing (F-15Es), Seymour Johnson AFB, North Carolina (the TICARRS 92 Operational Assessment site);
- 49th Wing (F-117As), Holloman AFB, New Mexico;
- 388th Wing (F-16s) and Ogden Air Logistics Center (ALC), Hill AFB, Utah;
- Oklahoma City ALC, Oklahoma;
- Sacramento ALC, California;
- Rockwell Corporation, Los Angeles, California;
- Lockheed (formerly General Dynamics) Corporation, Fort Worth Division, Texas; and
- McDonnell-Douglas Corporation, St. Louis, Missouri.

It was important to elicit views from a wide range of user communities because different kinds of activities use data for different things. Squadron and wing maintenance personnel, for example, largely interact with maintenance information systems in order to enter data, not to use them, although some repair personnel routinely retrieve data on the repair history of parts. Wing engine and TCTO management functions are supported by the

data systems, as is the tracking of aircraft inventory, utilization, and status. The MAJCOMs also use much of this same information.

Depot repair personnel, in some cases, use the maintenance information to assist with repair diagnoses. Equipment and item managers use the systems to identify persistent maintenance problems and to suggest candidates for future equipment modifications. Program offices and equipment manufacturers are also interested in pin-pointing problems that may require redesign work.

These visits gave us a baseline for judging how the information systems are currently used, how effectively they function, and what problems they have. When visiting users, we tried to gather information systematically by asking the following questions:

- Which information system do you use? How often do you use it?
- How do you use the information system to do your job? How much do you rely upon this information, verify it, supplement it?
- What standard reports do you generate?
- What customized reports do you generate? Do you have examples you can share with us?
- What functions are missing from the system?
- What operating characteristics are good or bad (timeliness, accuracy, accessibility)?
- How does the information requirement change for peace versus war? How does the adequacy of the system change?
- What resources are required to make the system work?

C. DISCUSSIONS WITH DEVELOPERS

Study team members met with the developers/maintainers of the systems in order to get a more detailed understanding of the systems' functions, hardware and software architecture, cost, status, and problems. All the relevant information system developers were visited at least twice:

- Litton Computer Systems, REMIS developer, Dayton, Ohio;
- Standard System Center, CAMS developer, Gunter AFB, Alabama; and
- Dynamics Research Corporation, TICARRS developer, Andover, Massachusetts.

We were particularly interested in the cost and likely effects of planned system improvements. We used as a general guide the items displayed in Table IV-1, making appropriate modifications for system-specific variations.

Table IV-1. System-Related Issues

System architecture	High-level description		
Hardware	Computer		
	Communications		
	Terminals		
Software	Operating system		
	Key utilities (e.g., data base manager, communications package)		
	Applications programs	genesis, age (by increment)	
		language(s)	
		size (by major component/function)	
		data base	structure (e.g., hierarchical, rational)
			number of records
			record size
			reporting/query language
Adaptability	Nature of previous improvements (scope, cost, schedule)		
Reliability/Availability	Amount of scheduled downtime		
	Percent up-time		
	Failure data		
	Diagnostics		
Security	Protection/authorization functions		
Ease of Use	Training		
	User errors		
	Screens (number and organization)		
	Data elements		
	Query/report generation tools		
Data Base Integrity	Data dictionary		
	Updating/modification process		
	Verification/modification process		
	Space/backup/archival management		
Support	Hardware and software maintenance		
	Computer operations		
Performance	Terminal response time		
	Number of simultaneous users		
	Transaction turnaround time		
Operational Environment	Dedicated/shared		
	Priorities, scheduling		
	Operational measures/criteria		
Application Development	Cost and schedule from previous increment		
	Size (lines of code)		
	Effort (staff-months)		
	Duration (months)		
Known Problems			
Planned Improvements	Description of each major improvement		
	Estimated cost and schedule		

D. LOGISTICS AND OPERATIONAL DATA

As described in Chapter III, two of the dimensions of effectiveness used to evaluate CAMS/REMIS and TICARRS were the effect of the use of the systems on logistics and aircraft operations. Measures of logistics effectiveness include failure rates, repair times, and required asset levels. Measures of aircraft operations effectiveness include status indicators, abort rates, and utilization.

IDA received data on such measures of effectiveness in the form of TICARRS data on F-15 and F-16 aircraft over the period 1982 to 1992. In addition, the CAMS/REMIS/TICARRS PMO provided IDA with a detailed time line of events pertaining to the implementation of and changes to each of the information systems.

IDA used these data, supplemented by information from the Air Combat Command, to analyze logistics and operational effectiveness as functions of the information systems being used.

E. COMPARISON OF CAMS AND TICARRS AT SEYMOUR JOHNSON AFB

Seymour Johnson AFB in Goldsboro, North Carolina, was the site of the special six-week Operational Assessment of TICARRS 92, beginning March 29 and ending May 7, 1993. During that period, Seymour Johnson personnel moved from CAMS to TICARRS. This assessment provided a unique opportunity for the IDA study team to talk to and observe the same users first with CAMS and then with TICARRS. The following subsections describe IDA's activities during the Operational Assessment.

1. Interviews and Observations

Before the TICARRS 92 assessment, we interviewed CAMS users from the following work centers at Seymour Johnson:

- Debrief,
- Flight Line Maintenance,
- Plans and Scheduling (wing and squadron level),
- Avionics Back Shop,
- Engine Management,
- Propulsion Shop,
- Data Base Management,

- Phase Inspection
- Supply,
- Weapons,
- Armament,
- Analysis,
- Maintenance Operations Center, and
- Training.

Users were asked to describe in general terms their responsibilities and their interaction with CAMS (input and output). They were also asked about CAMS functions, ease of use, response time, and availability.

We also observed users from the same work centers, except Plans and Scheduling at the squadron level and Training. An effort was made to observe during periods of peak interaction (e.g., observing Debrief during scheduled landings). Notes were made of any problems such as exceptionally long response times.

We returned to observe these same user groups (and when possible the same users) during the TICARRS assessment period.

2. Surveys

The TICARRS 92 Operational Assessment also gave us the opportunity to compare the levels of satisfaction of a given set of users with CAMS and TICARRS 92. To assess user satisfaction, IDA and the Air Force developed the 1993 Air Force CAMS User Questionnaire and the TICARRS Assessment Questionnaire. The former was distributed before the start of the assessment. The latter was administered three times—at two, four, and six weeks into the assessment. Copies of the questionnaires are included as Appendix C. Wherever possible, the questionnaires were constructed using the same language in order to elicit the same types of information about both CAMS and TICARRS 92.

The issues addressed in the questionnaires included:

- background information on the respondent, including pay grade, work center, job function, education level, and computer experience;
- length of experience with the system;
- frequency of system use;
- duration of use;
- verification of data;

- problems with the system;
- criticality of the system to the respondent's job;
- satisfaction with ease of use and understandability;
- satisfaction with ability to input and output data quickly and easily;
- satisfaction with ability to modify previously input data easily (a consideration for maintainers who make an initial entry, then might have to change it after making a final diagnosis or deciding exactly which parts need to be replaced);
- satisfaction with ability to use the system to perform both required and optional functions;
- satisfaction with accuracy of data received;
- satisfaction with documentation;
- satisfaction with system responsiveness; and
- overall satisfaction.

The questionnaires made extensive use of response options that constitute a Likert scale (a five-point scale often used for survey responses). The responses to questions about level of satisfaction included "very satisfied," "satisfied," "mixed/neither," "dissatisfied," and "very dissatisfied." A sixth possibility, "does not apply/don't know," was also provided. The Likert scale is desirable, because it has been shown that these options generate proportional responses; that is, the distance between a "very satisfied" and a "satisfied" response is the same as the distance between a "dissatisfied" and a "very dissatisfied" response.

The Air Force assessment team distributed the questionnaires in conjunction with its assessment. As many as 1,000 people participated, including flight line maintainers, data base managers, maintenance operations center personnel, and other key users.

IDA also helped the Air Force develop a survey addressing the quality of the training provided at the beginning of the assessment. The training survey had two functions: (1) to provide the Air Force assessment team with immediate feedback on the adequacy of the training so it could be fine-tuned as appropriate, and (2) to provide the Air Force and IDA with information on the effectiveness of training (and the ease of learning to use TICARRS) to be included in the evaluation.

To achieve the first purpose, the survey asked, for example, whether or not respondents understood that they were expected to use TICARRS 92 during the assessment and whether or not they felt able to use it. To achieve the second purpose, the survey asked

about satisfaction with the amount and content of the training and about the instructor's knowledge of TICARRS and of the respondent's job.

3. Functional Disconnects and Difficulty Reports

During the Operational Assessment, the Air Force Assessment Team took great care to document user problems with TICARRS 92. Particular attention was paid to the ability of TICARRS to provide users with the functionality they were used to getting from CAMS. Users experiencing problems filled out Functional Disconnect Work-Around Write-Ups (FDWWs). Over 400 FDWWs were filed, although many of them did not reflect problems with TICARRS functionality but were caused by data problems, communication problems, inadequate training, and so on, and the same problem was often raised multiple times. The FDWWs were an important source of information for our comparison of CAMS and TICARRS functionality.

The FDWWs were supplemented by Difficulty Reports (DIREPs) produced by Dynamics Research Corporation (DRC) personnel at Seymour Johnson. The DIREPs generally identify places where DRC felt it would be useful to modify TICARRS to enhance its functionality or ease of use. Most of the DIREPs fell into the category of bugs or minor modifications to system parameters. Many of the DIREPs led to modifications being made to the system during the Operational Assessment. Several areas of major missing functions (e.g., production scheduling) were identified, but not fixed during the Operational Assessment. The costs of fixing them were addressed in our study.

F. TEST OF REMIS FUNCTIONALITY AND SELECTED OPERATING CHARACTERISTICS

IDA conducted a detailed assessment of the current functionality and status of REMIS to compare the data output capabilities of TICARRS and REMIS. We gave the CAMS/REMIS Program Management Office and the F-15 System Program Office (TICARRS users) two identical data requests in late May 1993. The first data request (shown in Figure IV-1) gave three working days' lead time; the second (shown in Figure IV-2) was given upon our arrival at the respective Dayton, Ohio offices. The requests covered several aircraft types, and the data requested are typical of those we had seen requested by base, ALC, and MAJCOM users. The test focused on both: (1) the basic functions of REMIS and (2) specific areas of functionality that TICARRS users have requested be provided before TICARRS would be fully replaced by CAMS/REMIS. A more detailed discussion of the assessment and its results is contained in Appendix D.

REMIS Data Request—21 May 1993

1. Monthly, October 1992 through April 1993, for F-15E aircraft, 4th Wing:
   A. Mission-capable rates number and percent of aircraft FMC, PMC, and NMC
   B. MTBF and MTBMA by two-digit WUC
   C. Re-test OK rates by two-digit WUC
   D. MMH/FH by two-digit WUC
   E. Break rates
   F. Fix rates
   G. Abort rates—In-flight and before-flight

2. For all F-15s, worldwide, and for WUC 74 for first quarter 1993:
   –Overall MTBMA
   –Listing of all LRUs, by serial number, with more than three maintenance actions in first quarter 1993
   –Listing of all LRUs, by serial number, with MTBMA less than overall group average

3. For F-16, part number 1829003, for May 92 through April 93, list:
   Serial number, WUC (14DPO and 14DQO), tail number, total sorties, total maintenance actions, total maintenance man-hours, number of failures, number of removals, number of CNDs, number of repairs, number of NRTSs, narratives.

4. Algorithms in REMIS and REMISTALK for calculation of MC rates, MTBR, MTBCF.
   Example run comparing variables drawn from REMIS and REMISTALK to see whether or not they are the same.

Figure IV-1. First Data Request

CAMS/REMIS Data Request—26 May 1993

1. List of current TCTOs for B-1 from GCSAS
2. Seymour Johnson LANTIRN and backshop automatic test equipment status
3. For December 1992, F-16C/D at ACC:
   Mission-capable rates
   Flying hours
   Sorties
   Maintenance man-hours per flying hour
   Mean time between maintenance actions—Type 1, Type 2, Type 6
   Total number of aircraft
   Total man-hours
   Total failures
4. Approved and actual configuration for any tail number of the B-1
5. From CAMS, number of transactions, by month, January 1991 to latest available, for 4th Wing at Seymour Johnson AFB and 388th Fighter Wing at Hill AFB

Figure IV-2. Second Data Request

V. EVALUATION OF EXISTING SYSTEMS

This chapter provides a comprehensive view of the functions of the three information systems. The topics covered are as follows:

- Functionality—by major category (inventory, status, utilization, scheduling, debrief, Maintenance Operations Center (MOC), maintenance reporting and scheduling, supply system interface, engine management, cannibalization management, configuration management, Time Compliance Technical Order (TCTO) management, personnel training/availability/scheduling, shop production planning, mobilization planning, and deployment), and by user group (base, depot, MAJCOM, contractor).
- Scope—number (and location) of weapon systems and other equipment.
- Operating characteristics—system performance and technology (including availability, response time, system architecture, software, and operational management and control), ease of use (including observations/discussions with users and the formal survey taken at the Operational Assessment at Seymour Johnson AFB).
- Data accuracy and completeness—including Recovered Functionality (RECFU) II,[1] the accuracy of engine data, information drawn from the two-level maintenance experiment, analysis of data developed during phase inspections, other information on data loss, and the integrity and security of data input.
- Adaptability—including our vision of the future Air Force organization, management, and technology as it bears on maintenance information systems. This section addresses the capabilities of the information systems to accommodate new technologies, and the capabilities of the systems to move toward the evolving requirements of the future Air Force.
- Logistics and operational effectiveness—the information systems' affect on logistics measures of effectiveness and operational capability.

The chapter is necessarily long because it includes detailed information about the systems. It identifies system-specific deficiencies and provides the foundation for defining the alternatives, described in Chapter VI, and their costs, presented in Chapter VII.

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[1] RECFU II is a REMIS initiative to recover functionality that had been delayed due to funding cuts.

A. FUNCTIONALITY

1. Background

The functionality of CAMS, REMIS, and TICARRS refers to the types of tasks and actions that these information systems support during maintenance planning, scheduling, and performance. For example, the information system keeps track of the inventory of aircraft held by the Air Force, along with the record of the organizational units to which the aircraft are assigned and the units that actually have possession of them. The system also records the transactions dealing with an aircraft, including its original acquisition, its shifting among various organizational units and bases, its movement into depot, and ultimately its retirement. In addition the system records modifications and repair actions that have occurred on the aircraft. This function includes a large number of supporting and derivative system activities. Comparing the functions of CAMS, REMIS, and TICARRS is difficult because:

- there is no promulgated standard set of functions that the information system must perform,
- even where there is full agreement on a particular general function, the exact manner in which a specific system might carry out that function is not standardized, and
- each system has its own genesis, based on different perceived needs or requirements, and was designed and developed by different personnel and organizations. The systems are organized in different ways and use different terminology.

Nonetheless, it is critical to this assessment to identify and evaluate the range of functions that each of the information systems performs. It is also important to address the different sub-functions within a particular function because this affects the amount of software that must be generated to give the information systems, CAMS/REMIS and TICARRS, equivalent functionality.

2. General Assessment

In order to assess the differences in functionality between the systems, we examined detailed information on the tasks the systems are supposed to perform, the tasks they actually perform, and the various points at which they diverge. As an overview, Table V-1 lists 16 principal functional areas and some of the more important sub-functions included in the major areas. It also provides our assessment of which functions each information system includes.

Table V-1. System Function Comparison

Functions Compared	CAMS[a]	REMIS	TICARRS
a. Equipment Inventory			
Identification	X	X	X
Location	X	X	X
Assigned/Possessed	X	X	X
Transactions	X	X	X
History—base level	X	X	X
History—fleet		X	X
b. Equipment Status			
Current—base	X	X	X
Current—fleet		X	X
History—base	X	X	X
History—fleet		X	X
c. Equipment Utilization			
Current—base	X	X	X
Current—fleet		X	X
History—base	X	X	X
History—fleet		X	X
d. Flight Scheduling	X		X
e. Support MOC	X		X
f. Debriefing			
Flight profile, data, discrepancies	X		X
Work order generation	X		X
History—base	X	Narrative not now retrievable	X
History—fleet		Narrative not now retrievable	X
g. Maintenance Reporting and Scheduling			
Work-order generation	X		X
Maintenance planning and scheduling	X		
Job tracking	X		X
Time Change Item Scheduling/Tracking	X		X
Phase inspection	X		X
Failure histories	X	Narrative not now retrievable	X
Corrective action histories	X	Narrative not now retrievable	X
Reliability measurement		Difficult to retrieve at part-number level	X
Maintainability measurement		Difficult to retrieve at part-number level	X
Serialized part maintenance history	X	Not observed	X
Quality Control/Quality Assurance	X	X	X

Table V-1. System Function Comparison (Continued)

Functions Compared	CAMS[a]	REMIS	TICARRS
h. Maintenance-Supply System Interface			
Job site parts ordering	X		
Interface with configuration file	X		
Track status of parts order	X		
Mission capable, awaiting parts management	X		
i. Comprehensive Engine Management	X		
j. Cannibalizations Tracking/Management	X		Incomplete
k. Configuration Tracking/Management		X[b]	X
l. TCTO Management	X	X[b]	X
m. Personnel Training/Availability/Scheduling	X		
n. Shop Production Planning/Scheduling/Control	X		
o. Mobilization Planning			
p. System Deployability			
Deployable communications links	X		X
Deployable information system			X

Note: The letters to the left of the functions correspond to the letters of the subsections that describe them.

[a] CAMS functions are performed only at the base level.

[b] Not fielded; in testing.

Like any classification scheme, the structure of the list in Table V-1 has some arbitrary features. Some tasks, such as TCTO management, are considered major functions because of the emphasis placed upon them in the maintenance community or the amount of activity they involve. Regardless, the list serves as a convenient framework for organizing the comparison of system functionality that has resulted from our field trips, interviews, review of formal documentation, and observations of the TICARRS 92 Operational Assessment held at Seymour Johnson Air Force Base.

Table V-1 shows that neither CAMS/REMIS nor TICARRS has provisions for mobilization planning. TICARRS does not provide any of the sub-functions of a maintenance-supply system interface, nor does it provide a Comprehensive Engine Management System, a personnel training/availability/scheduling subsystem or a module for shop production planning/scheduling/control. CAMS/REMIS does not now provide a deployable system, though it can support deployed operations through communications links.

Of course, the simple assessment in Table V-1 gives no indication of how completely or how well the systems perform in any of the major functional areas. The speed and facility with which the systems perform the functions are assessed later in the

report. This section assesses the completeness of each system and the approach of each to the functions.

3. Specific Assessment

This assessment focuses on the relative strengths and weaknesses of each system with respect to the various functions. To the extent that some one or other organizational level has experienced or is concerned about the identified strength or weakness, that information is also included.

It is difficult to separate clearly the presence of a function in a system from the quality of the system's performance of that function. That is why the comparison shown in Table V-1 cannot fully describe the essential differences between CAMS/REMIS and TICARRS. Poor performance of a function may be as bad or worse than not having the function at all, and differences in the performance of one function may compensate for differences in the performance of others.

a. Equipment Inventory

CAMS and TICARRS have the capability for direct entry of equipment identification, its physical location, the organization to which it is assigned, and the organization that has actual possession. They also can enter transactions recording equipment gains and losses along with the information associated with the equipment being transferred. Because CAMS is a distributed data base, the records must be physically shifted when equipment is transferred from one CAMS base to another. The central data base feature of TICARRS fulfills this function by recording the change in ownership or possession, and other information does not need to be shifted because it is already available to anyone on the system. In the current versions of its conversations and screens, TICARRS identifies the organizational unit and base to which the aircraft is assigned but not the command or the program element of the Future Years Defense Program. Given the structure of the TICARRS database, adding identifier fields for the latter should be a relatively simple software maintenance task.

Part of the transfer process consists of scheduling and recording the 29 actions required for a transfer inspection. Accomplishing this is more cumbersome in TICARRS than in CAMS.

REMIS receives inventory records and transactions from CAMS. With the completion of RECFU II, this updating is to occur every hour and the discrepancies between CAMS and REMIS data over which earlier concerns were expressed are to be

reconciled. The MAJCOMs and Air Staff are the principal users of these REMIS data for planning and directing operations.

b. Equipment Status

This function records the availability of the equipment and its capacity (or incapacity) to carry out its assigned mission(s), along with the number of hours the equipment has been in various conditions. During the Operational Assessment of TICARRS 92 at Seymour Johnson Air Force Base (AFB), backshops were favorably impressed with TICARRS's ability to keep track of the status of the automatic test equipment (ATE) that is essential to repairing line replaceable units (LRUs). CAMS provides a similar function in its Automatic Equipment Reporting System based on the TICARRS approach, but it has not received wide-spread use. Also, the MOC personnel liked TICARRS's ability to give notice automatically when aircraft become "hangar queens" as their downtime accumulates. The quality of the REMIS data was generally thought to be equal to that of TICARRS data, but at one air base there was some concern about REMIS equipment status information.

As in the case of the inventory data, the MAJCOMs are principal users of the status information. In at least one instance, MAJCOM personnel felt that the edit and error correction procedures for the EIMSURS module of REMIS was causing a degradation in the timeliness and quality of its status information. Edits pushed back to the originator for verification or correction are retained indefinitely or until corrected. Those not corrected quickly are sent for review by the supervisor of the person who made the original entry.

c. Equipment Utilization

This function records the elapsed time of operation of each weapon system or piece of equipment. It may also make provision for recording other measures of use of the equipment such as sorties, touch-and-go landings, full landings, engine cycles, or number of tests performed. These data are entered into the information system by flight-line, staff, or shop personnel. CAMS receives directly from the Air Staff data on flying time allocations to each unit and reports comparisons of allocated versus actuals. Principal users of these data include the Air Staff, MAJCOMs, engine management, and plans and scheduling personnel. The latter two use the data for planning the inspections that are based on utilization rates. TICARRS does not have an interface with the K002 system through which the Air Staff allocates and monitors flying hours. It will need to develop such a capability.

At Seymour Johnson, there was a concern that engine utilization in TICARRS is measured only in hours and not in the other measures (cycles, afterburner, etc.) that are important to engine management. Squadron and wing staff had problems with the accumulated flight hours being produced by TICARRS but could not verify whether or not this might be due to the original CAMS data that were entered into the TICARRS system for the assessment. (Incorrect cumulative times adversely affect the scheduling of time change items.) At the Seymour Johnson assessment, it was very inconvenient to track sortie histories over a month since sorties could only be retrieved a day at a time with TICARRS.

Air Combat Command (ACC) personnel told the study team that they have been trying to rely on REMIS data to report MAJCOM-level flying-hour information to the Air Staff on a monthly basis. Data they receive have been incomplete and inconsistent, forcing them to obtain verbal reports from individual wings.

Through requests for data from the CAMS/REMIS Program Management Office (PMO) and the F-15 System Program Office (SPO), the IDA study team conducted a structured informal test of the effectiveness of the two systems' functionalities. A portion of these requests dealt with information on aircraft inventories, status, and utilization. Both systems produced numerical information that was within a few percentage points of each other for these various measures. However, due to difficulties created by the RECFU II effort, REMIS was not able to "find" the data for the full time period for which the information was requested.

d. Flight Scheduling

This function permits Air Force wing and squadron personnel to create, modify, update, and delete aircraft flying schedules. User assessments of CAMS/REMIS and TICARRS performance of this function did not appear to be substantially different. At the Operational Assessment, the observation was made that the TICARRS version takes more time. Also, concern was expressed that TICARRS does not facilitate viewing schedules over longer periods as well as CAMS does.

e. Support of the Maintenance Operations Center (MOC)

This function supplies the information needed in the MOC to keep detailed track of scheduled, in-progress, and completed aircraft flights, as well as the condition of non-flying aircraft. As Table V-1 indicates, both the CAMS/REMIS and TICARRS systems serve this function, but there are variances in their performances.

At Seymour Johnson, the MOC personnel observed that the Automated MOC (AMOC) portion of TICARRS does more than CAMS and with greater facility. AMOC automatically tracks a number of features, including crew ready time, crew show, engine start, and taxi time. CAMS relies more on hard-copy forms for some of these features and does not automatically flag deviations. The AMOC is considered more user-friendly than CAMS. At Langley AFB, personnel believe the CAMS version has all the necessary information but places a heavier burden on the MOC operations.

f. Debriefing

In this function, CAMS and TICARRS automate the procedure of recording, modifying, updating, or deleting information about individual sorties, mostly supplied by the pilots flying the sorties. The data include operating time, flight profile information, and aircraft system operating discrepancies. To report the latter of these, the CAMS version of debriefing uses Automated Aircraft 781-Series Forms, a separate subsystem that serves other CAMS functions as well. Provision is also made for automatic generation of maintenance work orders.

There are few important distinguishing features between CAMS and TICARRS in this function. Debriefing personnel were generally satisfied with either. At Seymour Johnson, however, debrief personnel reported that CAMS is more difficult to learn, that the CAMS manuals are not reliable, and that error-correction with CAMS is more difficult, possibly involving the data base manager's assistance. Wing staff at Langley AFB think that the ability to retrieve from REMIS narrative information transmitted to it from the CAMS debrief would be extremely helpful. However, TICARRS must develop the capability to generate the Automated Aircraft AFTO-781 Series Forms if it is to have equivalent functionality, especially with respect to the strategic bomber portion of the ACC fleet.

g. Maintenance Reporting and Scheduling

The maintenance reporting and scheduling function deals with initiating, scheduling, and tracking both on-equipment and off-equipment repair work, both scheduled and unscheduled. As shown in Table V-1, it covers a wide range of sub-functions.

Both CAMS/REMIS and TICARRS have modules that carry out these sub-functions but their approaches differ significantly in some instances. TICARRS is weapon-system-oriented and predominantly takes the approach of recording events, whereas CAMS

is work-center- or event-oriented and is more proactive in supporting required maintenance activities.

While the features of both the CAMS and TICARRS work-order generation were generally considered to be quite good, some flight-line personnel at the Seymour Johnson assessment believed the process to be easier in TICARRS because its screens and error messages better facilitate the data entry. However, it was also observed that TICARRS makes a "remove" action without a corresponding "replace" action (a common occurrence when configuration changes are being made to an aircraft for a mission) more difficult. In TICARRS, the closure of such a remove action must be made by the technician's supervisor, a requirement that TICARRS advocates claim imposes more discipline and information accuracy on maintenance data entry. Shop personnel also observed that while TICARRS does permit one work center to create work orders for other work centers, those work orders do not load the other work centers under the same job control number, a major advantage of CAMS.

The observations regarding maintenance planning and scheduling and job tracking were mixed. For some sub-functions people favored CAMS/REMIS, for others they favored TICARRS.

At Seymour Johnson, the consensus was that scheduling is done more easily in CAMS than in TICARRS (TICARRS focuses on maintenance events in terms of the aircraft, not on the work centers where the repairs are carried out). This applies to job tracking in the shops as well. There was almost total agreement at all levels of operations and staff that TICARRS needs a display like the CAMS screen 380, which permits tracking of open work orders by work center. CAMS also gives a better snapshot of the work that has been performed on a particular job-control number (JCN).

Another difficult problem for TICARRS was the required 14-day records check, which reviews the records of inspections, time change items (TCIs), open discrepancies, engine data, and so on, of a specific aircraft (for all aircraft) as of that time. CAMS performs this automated records check using four screens whereas TICARRS cannot perform this function directly from any screen. At Seymour Johnson, it was claimed that TICARRS could perform this through a query, but the Assessment Team reported that the query did not work. Moreover, having to use a query to carry out this function is more laborious and time-consuming than it should be for such a routine requirement.

Both CAMS and TICARRS carry out TCI and inspection scheduling. At Seymour Johnson, production and scheduling personnel observed that CAMS requires calculation of

the TCI due dates off-line and manual entry through several screens, whereas TICARRS calculates and enters them automatically once installation of the part on the aircraft is recorded in the system by its work unit code (WUC). Personnel encountered difficulties using TICARRS in tracking work related to inspections because it accounts for work by part and not by work center, particularly when multiple work centers were involved. Finally, a minor rigidity or omission in TICARRS was reported. While it provides for recording narratives for TCIs, TCTOs, and the "fix" portion of inspections, it has no such provision for the "look" part of inspections.

Concern was expressed for how well CAMS can track work on those LRUs that may be repaired in a two-level maintenance context (i.e., where the LRUs are removed and replaced at the flight line and moved directly to the depot) without any work being done at the intermediate level. CAMS immediately loses sight of the part once it leaves the base maintenance and supply systems, whereas TICARRS continues to keep track of it (serially tracked items only) because it is always in the TICARRS central data base that users access directly. In CAMS/REMIS, REMIS has the fleet-wide information needed to support two-level maintenance, but base-level users do not have access to REMIS directly through their CAMS terminals.

The functions involving failure and corrective action histories and reliability and maintainability data are largely carried out by REMIS and TICARRS. CAMS is oriented to base-level activity and does not retain historical data indefinitely. Consequently, the scope and extent of its data base are limited by design for performing these functions. Within REMIS, the Product Performance Subsystem performs this function, but it is not as well received as TICARRS. REMIS receives narratives from CAMS but can retrieve them only through the less-convenient means of specific queries or its ad hoc language, REMISTALK. At the F-15 and F-16 SPOs, concern was expressed over REMIS's inability to track reliability and maintainability (R&M) information by aircraft block number. They also want assurances that REMIS contains complete histories (without gaps) before they have to rely on it solely. Before the fielding of REMIS, the B-1B contractor created its own central data base, gathering CAMS input directly from the various bases where that aircraft is stationed. It apparently continues to do so rather than rely on REMIS. Other contractors insist that they still need the D056 system tapes because they are unable to retrieve the data they need from REMIS.

Observations about TICARRS are generally more positive. Personnel in the repair shops liked the ability of TICARRS to give them part or LRU histories. The F-15 and F-16 SPOs rely on fleet-wide visibility from TICARRS for histories and R&M data. The

narratives contained in the histories provide a significant advantage over REMIS. The F-16 SPO attributes a significant portion of the credit for that aircraft's success to the fleet-wide visibility of the data in TICARRS and its contribution to quick problem correction. Contractors would like longer time series to be available on-line in TICARRS but concede the off-line retrieval to be adequate.

Members of the maintenance community at the shop, depot, and SPO levels were very positive about TICARRS's long, fleet-wide serialized part maintenance histories and the ability those histories give analysts to identify and track bad actors (although there is concern because TICARRS's data presently is only as good as the CAMS data that feeds it). CAMS is unable to do this because of its individual-base orientation. Some users have been able to use REMIS to track repair histories, and the capability to track bad actors has been demonstrated using REMIS information at one depot, Oklahoma City ALC.

Finally, the CAMS and TICARRS Quality Control/Quality Assurance functions each consists primarily of a Product Quality Deficiency Report (PQDR) capability. This is a direct-entry function that reports known or suspected deficiencies of equipment, weapon systems, or related components. Since TICARRS has not been on direct entry for several years, its function apparently has not been modified to conform to the latest technical orders on PQDRs. As a consequence, at the Seymour Johnson Operational Assessment, the 4th Wing resorted to the CAMS PQDR routines. The Assessment Team also observed that TICARRS does not make provision for allowing the screening officer in quality assurance to return the PQDR to the originator for modification or closing—a capability CAMS does provide.

The results of the IDA data request to the CAMS/REMIS PMO and the F-15 SPO reinforce some of the impressions and opinions gathered during field trips with respect to the systems' abilities to provide R&M information. Both REMIS and TICARRS produced aggregate information on maintenance man-hours, mean times between maintenance actions, and total failures in response to the requests. For REMIS, much of this information was obtained using REMISTALK. However, when the request was made in terms of a given part number or specified that the information be reported by LRU serial number, the REMIS PMO either did not supply the information, stated that it did not have the capability to produce it, or supplied similar information for the wrong dates and model of aircraft.

h. Maintenance-Supply Interface

This function facilitates the information system's working directly with the Standard Base Supply System (SBSS) rather than through a separate SBSS terminal. As a result, the user is able to order parts directly from the job site and work directly with the configuration file to confirm that ordered parts are authorized and available for use on the equipment to be repaired. The user can track the status of ordered parts and manage the allocation of any parts that are causing aircraft mission status problems or have caused awaiting parts status in component repair.

TICARRS has no provision for such an interface, and that is considered to be a major deficiency. Its ability to track the status of ordered parts is limited to the technician's making separate status inquiries through the SBSS terminal and manually entering the information into its related screen. Repair shop personnel, particularly in the Avionics Shop and the LANTIRN (Low Altitude Navigation and Targeting Infrared System for Night) shop, expressed a major concern because job-site-part-ordering capability and ordered-part-status tracking are extremely important to their operations. Another aspect of their concern was that without the interface, there was no edit check to assure that proper parts numbers were being used. Similar concerns were expressed at the depot level.

i. Comprehensive Engine Management

This function treats aircraft engines like an end item rather than a component on the aircraft. The function collects engine status and engine component operational data that are essential to tracking and changing life-limited serially controlled items on the engine. The function ties into the Comprehensive Engine Management System (CEMS) central data base at the Oklahoma City ALC to permit fleet-wide tracking of depot visibility and analysis of all engines in the system.

As Table V-1 shows, CAMS supports CEMS reporting and interfaces directly with CEMS. TICARRS treats engines like other aircraft components or LRUs for purposes of collecting and tracking engine maintenance information, it does not interface with CEMS. During the TICARRS Operational Assessment, wing operations continued to use this function in CAMS because of the importance of the information it supplies to engine management and maintenance and the relationship of the engine operations to flight safety.

j. Cannibalization Tracking and Management

When a part is not available in the supply system, authorization may be given to remove a part from one aircraft to fill a hole in another. The cannibalization and tracking

management function keeps track of the receiving and donor aircraft and the status of the part on-order. It also helps item managers to allocate the supplies of the part to fill the resulting hole. Without this oversight, a sequence of cannibalization actions for the same part could easily obscure the identity of the aircraft with the original failure.

Both CAMS and TICARRS have versions of this function. However at Seymour Johnson, line and supply personnel were not as satisfied with the TICARRS version. TICARRS did not provide a full audit trail of sequential cannibalization actions as a part is moved across several aircraft. Each cannibalization action required the opening of a new work order and JCN documentation, including the order placed on the supply system (partially the effect of TICARRS not having an interface with the SBSS). TICARRS can trace a particular part through a sequence of cannibalization actions only by way of a special computer run, such as a part maintenance history or a specific query run in background. The CAMS procedures to trace the series of cannibalization actions that a particular part may have had were reported to be less cumbersome. Also TICARRS did not, at the time of the Operational Assessment, support cannibalizations from removed engine to installed engine. While provision was made for such an action subsequently, it was not used in the course of the assessment.

k. Configuration Tracking and Management

The configuration management function consists of maintaining the list of part numbers that are authorized to be included on an aircraft or in a particular LRU of the aircraft, by quantity and location. It updates the authorized list of parts as changes are made due to modifications. It also keeps track of the parts (down to the serial numbers, where applicable) that are actually on each aircraft as remove-and-replace actions occur.

Opinion about the configuration function of TICARRS was generally higher than that of CAMS. As indicated in Table V-1, the REMIS configuration function has not been fielded but is currently in testing.

It should be noted initially that because it is a distributed system, CAMS only keeps track of authorized and actual configuration for the base at which the CAMS user is located. Consequently, edits and checks for consistency are not fleet-wide in CAMS as they are in TICARRS. In CAMS, at any one time, a particular serial number might be credited against two aircraft in two different locations with detrimental effects on any attempts to track the performance of the specific serially controlled part.

Apparently, control of the configuration data is much looser in CAMS. For example, at Seymour Johnson, personnel reported that a larger quantity of a particular part

can appear to be on a specific aircraft than is either authorized or can physically be installed. This caused problems when CAMS data were loaded into TICARRS for the Operational Assessment, because TICARRS rejected data that its edits identified as being inconsistent with the configuration of the aircraft.

Flight-line personnel reported that TICARRS was more rigorous in its treatment of configuration items and allowances for deviations, including serial number discrepancies. Shop personnel reported that they preferred the rigor required to change configurations in TICARRS. Also, they found the fleet-wide visibility of all serial numbers of a part to be helpful for troubleshooting and repair actions.

In discussions about the REMIS configuration function, the F-15 and F-16 SPOs expressed concern about the CAMS/REMIS capability to deal with configurations by aircraft block number. Personnel at the Oklahoma City ALC believed the REMIS capability would be extremely important to its effectiveness.

l. TCTO Tracking and Management

This function provides an on-line capability for creating and automatically transmitting Time Compliance Technical Orders. It also updates the tasks to be accomplished under a TCTO, creates the work orders, and tracks and monitors the progress made against actions taken. In addition, it initiates orders for the necessary parts/components.

The REMIS capability for this function is part of the Generic Configuration Status Accounting System (GCSAS) that, as previously noted, has not yet been fielded. The judgments on the CAMS and TICARRS versions include pluses and minuses for both.

At the TICARRS Operational Assessment, flight-line and wing staff observed that CAMS facilitates the scheduling of many backshops directly and simultaneously if work in several is required for a single TCTO. In contrast, TICARRS must schedule work in the backshops individually and through Production and Scheduling. Flight-line personnel were also concerned that TICARRS TCTO management did not take into account other maintenance actions. CAMS, because of its interface with SBSS, automatically orders TCTO kits and monitors the status of kits, a function that TICARRS does not have. There was some difficulty surrounding just what maintenance actions would close a TCTO and the extent to which a particular shop's completed actions remained open as long as other shops' actions were not closed.

Personnel at the Ogden ALC believe that TICARRS has a significant advantage in its ability to track TCTOs by aircraft block number, whereas CAMS cannot. The F-16 SPO considers the TICARRS TCTO information to be more reliable.

In response to its data requests of REMIS, the study team did receive a listing of the TCTOs that were current for a particular B-1 aircraft. This list was obtained from the GCSAS module of REMIS, which is currently in testing. At the time, the approved configuration for the B-1 was not complete and the actual configuration had not yet been loaded in GCSAS, so it was not possible to demonstrate those features.

m. Personnel Training, Availability, and Scheduling

The personnel functional area provides an on-line means of managing and monitoring the training needs and achievements of the maintenance personnel. It also keeps track of the availability and skills of those personnel and helps in scheduling their duty stations and times.

CAMS has a personnel availability module that was fielded in the fall of 1992. TICARRS has no provision for this set of functions. The importance of this function was confirmed by the fact that during the TICARRS 92 Operational Assessment, the 4th Wing was granted permission to work around this TICARRS functional deficiency by continuing to use the relevant CAMS module. However, this difference in functionality may be temporary. The Air Force has a number of initiatives under way that might provide a new approach to training management systems.[2] It is possible, therefore, that the training management functionality included in CAMS could be replaced by another system and thus place TICARRS at no disadvantage relative to CAMS in this area. For now, however, this cannot be assumed.

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2 One such initiative is called Bright Flag, currently under development/review by ACC. Its purpose is to provide a more formal structure to career training and education, enhance training/education, and improve monitoring of training and education activities. It is to be a paperless system and follow an individual throughout his/her entire military career (replacing the G23 document now). Bright Flag evolved from a system called Base Training System, which was an Air Force Materiel Command initiative, developed by McDonnell-Douglas.

Bright Flag applies to all officers, enlisted personnel, and civilians. Bright Flag focuses on job skills training, quality improvement training, and professional and continuing education. The intent of the program is to expand productivity while force structure declines, provide tools to support professional and personal goals, and produce a highly qualified workforce. Portions of Bright Flag are being field tested now. Feedback is being received by ACC on the content of the program. While it appears that ACC will implement Bright Flag concepts, it is not clear whether the rest of the Air Force will adopt these initiatives.

n. Shop Production Planning, Scheduling, and Control

This function is an on-line planning and scheduling tool that lays out the daily, weekly, and monthly production schedules for the various work centers in the repair shops and transmits these schedules automatically to those work centers. Its focus is on the equipment resources needed to carry out the assigned workload. CAMS has an Automated Scheduling Module which was fielded in 1988 and works in a separate, personal computer environment. TICARRS does not have a counterpart; its reporting of removed "due-ins" is limited in assistance to shop supervision's scheduling of their shops' workload.

o. Mobilization Planning

The mobilization planning function consists of keeping track of all the manpower and equipment requirements and the steps required for an effective deployment of the fighting unit to a remote conflict.

Originally CAMS was to have a module that would interface with the Contingency Operation/Mobility Planning and Execution System. However, this function was later determined to be not cost effective and, therefore, unnecessary. Manual procedures, using in part the CAMS capability to identify personnel to a given Mobility Group Number, now satisfy Air Force requirements.

During the Operational Assessment, MOC personnel observed that TICARRS's automated version of the MOC (AMOC) is able to generate flow plans that would facilitate planning for the fighter/bomber (non-mobility) portion of mobilization planning.

p. System Deployability

This function provides for the deployment of manpower and equipment resources needed to set up the information system in support of the fighting units in theater. The requirements determination process has been under way for some time, but for the present, Air Force requirements for this function have not yet been formally defined.

During Desert Shield/Desert Storm, CAMS demonstrated its ability to deploy a suite of communications hardware that maintained a connection to the aircraft's home base. TICARRS also made provision to communicate data for Torrejon-based F-16s back to its CONUS installations but was not authorized to activate its commercial telecommunications link. On the basis of its Remote Engineering Data Acquisition Program, the Smart Data System (SDS) fielded a stand-alone system (operated on several personal computers) to support maintenance data reporting functions for deployed aircraft. This operation by SDS,

while employed without a formal Air Force requirement for deployability, served the purpose of maintaining the F-117 weapon system during Desert Shield/Desert Storm.

ACC leadership believes that uncertainty about the continued availability of communications links during a conflict and the need for quick access to information tailored to support ad hoc deployments make it necessary to be able to deploy part of the maintenance information system itself, not just to deploy a communications link. ACC is leading an effort to develop Air Force-wide requirements for a deployable CAMS system. ACC believes that a deployment system must:

(1) be rugged, portable, and available on the eve of the deployment;

(2) extract a subset of data from the full data base, including:

- TCI and phase inspection,
- status,
- aircraft records,
- debrief, and
- Job Data Documentation (JDD);

(3) be able to backfill information on new aircraft;

(4) have a physical setup (buildings, phone lines, etc.), and;

(5) update the home station (daily, etc.).

CAMS cannot support such deployment today. TICARRS, because of the SDS experience in the Gulf War, appears to have some advantage over CAMS in this area. This issue is discussed further in the section of this chapter on adaptability.

4. Conclusions

This review of the functions included in CAMS/REMIS and TICARRS indicates that both systems have their strengths and weaknesses. CAMS/REMIS has less capability to track serial-controlled parts, to identify bad actors, to produce accurate information on aircraft configuration, and to provide adequate failure and corrective action histories. Its support of the MOC provides less functionality than does TICARRS.

TICARRS has serious holes in its functionality as well, including its lack of an interface with SBSS, an interface to the CEMS, a shop scheduling management module, and a more facile means to perform the 14-day (automated) records check. The chorus of

pleas during the Seymour Johnson Operational Assessment for a TICARRS counterpart to CAMS screen 380 is an example of a lower-grade functionality.

On balance, TICARRS is entirely missing a larger number of important elements of functionality than is CAMS or REMIS.

B. SCOPE

CAMS/REMIS and TICARRS gather and manage information on different weapon systems and other (support) equipment. CAMS/REMIS can gather and manage information on many kinds of aircraft and other products, including communications-electronics equipment, automatic test equipment, and other ground equipment. To date, TICARRS (and SDS) has been used with only three types of aircraft, F-15s, F-16s, and F-117s, as well as with automatic test equipment and trainers.

Scope, the number of different systems or equipment types handled now, clearly influences the relative difficulty and cost of using the systems to fulfill the information requirements of the Air Force. The primary dimensions of comparison for system scope are:

- number of weapon systems, which includes number of different aircraft types and models, and
- other equipment supported by the information system.

We also need to be aware of the number of bases using the system, since introducing a new maintenance information system at a base (even one that is home to a kind of aircraft that uses the system elsewhere) can be an expensive proposition.

Regarding the number of weapon systems, TICARRS, if chosen as the preferred system, would need to have the following aircraft designs added to its data base operation: F-4, A-10, F-111, B-1, B-2, B-52, KC-10, KC-135, T-1A, T-37, T-38, T-39, T-41, T-43, C-12, C-20, C-21, C-22, C-23, C-26, C-130s, VC-137s, E-3, E-4, H-1, H-3, H-53, and H-60. Many of these have more than one series that would have to be accommodated. Missiles and simulators would also have to be added.

If the weapon systems on G081 (C-5, C-141, and C-17) are to use the same maintenance information system as other aircraft, they should also be considered in this evaluation. The cost estimates in Chapter VII do not include the costs of converting these aircraft to a new information system.

The second dimension of scope concerns support of other equipment. For example, at base level, CAMS currently handles equipment that support the following functions and users that are not included in TICARRS:

- flying-squadron-level command section, intelligence, life support, and operations support;
- operations support for the wing (including safety, command post, microcomputers, inspection support, programs and mobility, group commander, scheduling, mission planning, information systems support, standardization/evaluation, supply liaison, air traffic control (ATC) and ATC support functions, operations maintenance support supervision, airfield management, various weapons and flight command and control functions, operations support squadron commander, load standardization, intelligence, orderly room, weather, life support, weapons, flying training, and operational plans);
- logistics support (including commander, orderly room, programs branch, plans, maintenance university, training and administration, engineering technical services, and any maintenance complex self-help projects);
- equipment maintenance support (including aerospace ground equipment, production control, combat munitions, the Base-Level Combat Ammunition System, trailer maintenance, combat support, munitions storage, transit alert, munitions inspections, munitions supply, munitions branch, orderly room, and commander);
- component repair support (including orderly room, commander, and precision measurement equipment); and
- wing-level organization.

The list, which includes communications-electronics equipment and other kinds of equipment, is drawn in part from a compilation of functions that remained on CAMS during the Operational Assessment at Seymour Johnson. CAMS/REMIS support for communications-electronics equipment goes beyond aircraft operating bases, and includes support for space-related equipment.

C. OPERATING CHARACTERISTICS

The effectiveness of maintenance information systems extends beyond functional capability and scope. The operational characteristics are a measure of how well the systems perform the functions and capabilities provided by the system design in an operational or user environment. In evaluating the operating characteristics of CAMS, REMIS, and TICARRS, the study team focused on three key aspects that encompass the issues

identified by current and prospective system users. They are: system performance and technology, data integrity and security, and ease of use.

1. System Performance and Technology

This subsection evaluates those operational characteristics related to system performance and technology. In particular, availability, response time, system architecture and software design, operational management and control, and continuity of operation are evaluated for each system.

a. Availability

System availability is a measure of the time the system is available compared to that scheduled. This is usually expressed as a ratio or percent of scheduled available time less unscheduled down-time relative to scheduled time.

In practice this measure relates to the central computer, and does not necessarily reflect the availability of the system as seen by the user. The availability of the system to the user is determined by not only the central computer, but also by the availability of the communications links and terminal equipment being used. It is further complicated if the central computer is being shared by several applications [as with the Standard Base Level Computer (SBLC) and CAMS]. The user often cannot tell if the computer failed or if the application software failed (although it makes no difference to the user). On the other hand, if the central computer is not available due to unscheduled down time, it is clear that all the users are affected and therefore it is a useful starting point for an assessment; it provides an upper bound to what CAMS, REMIS, or TICARRS availability looks like to the users. If the central or host computer experiences low availability over a prolonged period, the continual interruption in service becomes the primary issue for both managers and user, and other operating characteristics are of secondary importance.

None of the systems under study measures communication link busy calls or outages, or terminal outages in a way that reflects availability from a user perspective. Our analysis was limited to the data available, specifically, central computer system availability data for all three systems, and the CAMS system availability as reported by the SBLC PMO at the Gunter Standard Systems Center (SSC). The data on the central computer system's availability report the percentage of time the central computer was operational and available for use. The data on CAMS availability report the percentage of time the CAMS database was available for processing user transactions. As stated earlier, these data do not take

into consideration any equipment outages due to terminal failure or communications equipment failure.

- TICARRS System Availability. TICARRS is meant to be available 24 hours per day, 7 days per week for on-line users. System availability was measured at 99.3 percent over a 5-year period.
- REMIS System Availability. The REMIS Operational Performance Parameters (11 January 1993) set objectives of 100 percent availability, 24 hours per day, 7 days per week as the production baseline. REMIS demonstrated 99.82 percent availability over a 180-day operational assessment period. In addition, the availability rate of the five REMIS remote node processors was 99.8 percent over the same period.
- SBLC System Availability. The SBLC operational performance requirements are 24 hours per day, 7 days per week for on line users, with an availability objective of 95 percent. The SBLC PMO at Gunter SSC provided data for the months of May and June 1993, which reported the up-time of many of the base-level SBLC systems. (Data were not available from all bases.) The uptime reported by bases ranged from 97 percent to 100 percent, many reporting uptime of 99 percent or better. The overall 24-hour average was 99.36 percent for the month of May for 45 reporting bases and 99.06 percent for 37 reporting bases for the month of June.
- CAMS System Availability. The CAMS Operational Performance requirements are 24 hours per day, 7 days per week for on-line users, with an availability objective of 95 percent , the same as the SBLC systems. Figure V-1 is a graph of the availability for all of the CAMS systems associated with active Air Force flying units for the period 15 February through 15 May 15 1993. The graph shows the availability of each system in terms of deviation over or under the goal of 95 percent availability.

The TICARRS, REMIS, and SBLC computer systems are operating at the top end of the practical realm of availability given the equipment configurations and the nature of the applications.

CAMS, on the other hand, suffers from an apparently wide variance in availability from base to base. The relatively poor showing of many of the CAMS systems may be attributable to the differences in automatic data processing (ADP) support and system management skills between bases. It is apparent that the availability of CAMS is not attributable to unavailability of the SBLC computer system.

CAMS system availability is sometimes influenced by operational decisions made at the base level. Some bases routinely operate the CAMS system for less than 24 hours a day. Virtually none of the CAMS systems is available seven days per week. The data in

Figure V-1 reflect only those days the CAMS system was in operation, weekends are not counted as scheduled days. In addition, appropriate adjustments were made for bases that routinely close in the late afternoon. Especially when non-operating days, weekends, and routine early closings are factored out (as they have been in the figure), it is not clear how often the decision to shut CAMS down coincides with the needs of maintenance personnel. Sometimes it may, but discussions with wing-level personnel at several locations indicate that CAMS is often taken down routinely at times that are inconvenient for maintainers who have to work at night in order to prepare aircraft to fly in the morning. This happens when data base managers or administrators purposely shut CAMS down in order to do maintenance on the data base.

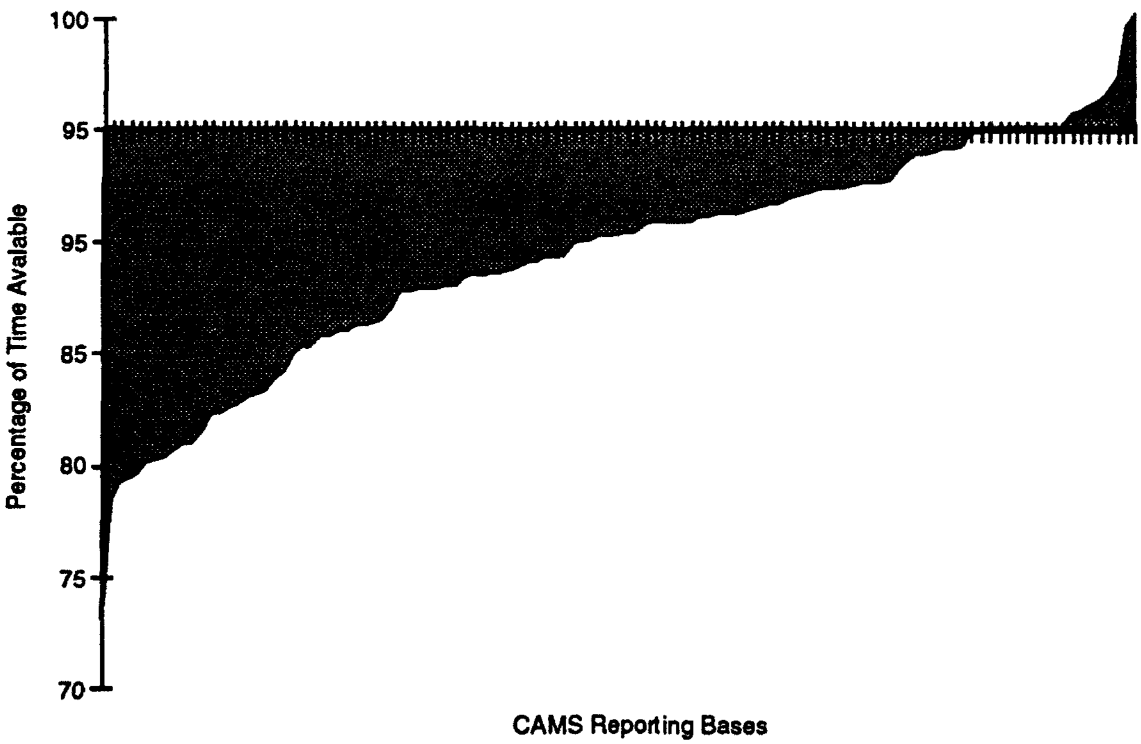


Figure V-1. CAMS Availability on SBLC Systems

Another reason for the variation in availability may be due to errors in the CAMS software that create errors in the data base. When this happens, it is sometimes necessary to stop the operation of CAMS and repair the data base. The extent to which any of the causes suggested are major problems is speculative without more definitive data. Nevertheless, the impact on the users is the same regardless of the reason (aside from decisions to turn CAMS off at times when maintenance activity is not taking place). If the system is not available when they need it, their ability to do their job is impaired and data may be lost.

b. Response Time

System response time is a measure of the information system's capacity to handle the required input and produce the required output at a rate appropriate for the users. The factors affecting response time are many: power and speed of the computer, design and efficiency of the software, speed of communication links, type of terminal equipment, amount of workload, type of applications, and type of operational management play important roles in determining the responsiveness to user input.

For the purposes of evaluation, our analysis focused on the response times of two generic types of input and output, or transactions. The first is a relatively simple type of transaction (e.g., a record update or a simple data query). This transaction typically involves entering data at the terminal, depressing a transmit key, and transmitting the data to the computer, which acts upon the data by retrieving a record, updating it, and sending a copy of the updated record back to the terminal operator. A simple query involves essentially the same process, except the computer would omit the update activity and send back one or two screens of report data.

The second type of input and output transaction is procedurally the same as that described above for a simple query, except that it is generally more complex and the output report contains significantly more data and is frequently sent to a printer rather than the terminal display for examination by the requester.

The measurement of the response time starts when the terminal operator depresses the transmit key and ends when the operator receives a response to the transaction at the terminal. The response time for each of the transaction types described above can be decomposed into two segments, data transmission and translation time and central computer processing time.

Unfortunately, the mechanisms used to capture response time data often do not include the data transmission and translation times. This is indeed unfortunate, since response time problems are frequently caused by an overloaded Data Communication Processor (DCP) or overloaded data communication lines. Discussions with technical personnel at each of the development sites provided insight into typical data transmission time. The data transmission time incurred at the base level is about 2 seconds. However, this can vary significantly if the communication equipment is overloaded.

The response time data provided for the three systems under study address the response time for a transaction at the central computer. To get an idea of the response time

seen by the user sitting at a terminal, about 2 seconds should be added to the average response time measured at the central computer.

(1) **TICARRS.** Since TICARRS has been limited to accepting maintenance data via CAMS since 1989, the study team took advantage of the TICARRS 92 Operational Assessment. During the assessment, the number of daily transactions was recorded along with the central computer processing time for each transaction. Table V-2 shows the number of weekly transactions over the six weeks of the assessment, the average number of daily transactions over a 24-hour period (5 days per week), and the percentage of the daily transactions with response times less than 3 seconds.

Table V-2. TICARRS Performance Data

Week Number	Transactions per Week	Transactions per Day	Percentage Under 3 Seconds
1	139,077	27,815	94
2	196,114	39,223	97
3	197,509	39,502	99
4	203,302	40,660	99
5	207,823	41,565	99
6	295,704	59,141	99

As indicated by the data, during the first week of the assessment 6 percent of the transactions took more than 3 seconds of processing at the central computer. In addition, the DCP at Seymour Johnson was overloaded and contributed to relatively slower response times during the first two weeks of the assessment. Adjustments made to the DCP resulted in reported response times of 3 seconds or less for 99 percent of the transactions during the rest of the period. If we assume a data transmission contribution of about 2 seconds for each transaction, 99 percent of the TICARRS transactions over this period would be less than 5 seconds.

The response time for the second type of transaction (more complex and lengthy output) was not measured; however, members of the IDA study team observed the response time of these type transactions to be no more than several minutes from the time of request to the start of the report generation at the requester's printer. Considering the complexity of the queries and the quantity of the data processed, the response time for complex queries was acceptable.

Study team observations indicated that the response time for standard reports were no more than 25 to 30 minutes for a lengthy report.

During the six-week assessment, the TICARRS system was sharing the central computer with other activities and users. The Seymour Johnson transactions accounted for an average of 2.64 percent of the computer utilization for each days operation, peaking at 4.6 percent during heavily used periods. Even though the TICARRS application was sharing the central computer with other applications and users, the transaction response time at Seymour Johnson was relatively good.

The assessment showed that TICARRS can provide adequate system response time given that the computer system is not overloaded and processing tasks are properly prioritized. Nevertheless, it is the view of the IDA study team that the computing power of the existing TICARRS systems would need to be substantially increased (about 4 times more power) to maintain satisfactory response and throughput to support the full complement of Air Force weapon systems and functionality now provided by CAMS/REMIS.

(2) **REMIS.** The REMIS system response time data is based on the operation of REMIS during January–May 1993. At that point, REMIS was not fully operational. Two of the three major components were available for use throughout the Air Force, while the third component (GCSAS) was undergoing field evaluation and was not to start operational test and evaluation until the third quarter of calendar 1993.

One of the main functions of REMIS is to collect and give access to maintenance data on a fleet-wide basis. REMIS must collect data from several different sources (CAMS base-level input, for example) and it must distribute data to other information systems within the Air Force. It should be remembered that the responsiveness of REMIS may be affected by its need to handle the workload imposed by these activities in addition to responding to user transactions and queries.

Table V-3 shows the current (January–May 1993) system response times, and corresponding computer utilization and report production compared to the target capability projected for September 1992.

Examination of the table reveals that while one of the REMIS central computers (HQ1) appears to be operating near the maximum desired capacity (60 percent). The other is operating at only 15 percent of capacity, demonstrating a load-balancing problem. The average number of daily users is about 95, who account for an average of 226 log-ons per day. This is substantially lower than the number of projected log-ons, indicating there is quite a potential for growth. (There were 2,600 individuals authorized access in February 1993).

Table V-3. REMIS Performance Data

Topic	January–May 1993 Measurement	September 1992 Projection
HQ1/HQ2 average computer utilization	HQ1 = 57% HQ2 = 15%	HQ1, HQ2 = 68%
Number of standard reports per day	120	1,000
Average processing time per report	2.4 hours	1.2 hours
Average number of REMISTALK reports per day	30	500
Average REMISTALK processing time per job	7.5 hours	8.5 hours
Average transaction (query) response time (computer processing)	4 seconds	4 seconds
Average number of users per day	95	Unknown
Average number of log-ons per day	226	800

Benchmark measurements of REMIS query transactions and configuration table maintenance transactions indicate that the response time for the simple transactions are in the range of 3 to 4 seconds per transaction (central processor time). The more complex query transactions were measured in the range of 12 to 13 seconds response time.

Average processing time for a report is higher than projected (averaging standard reports and REMISTALK reports) and the number of reports is substantially less than projected in September 1992. The September 1992 projections were based on performance simulation runs, which, in turn, were calibrated against the actual REMIS processing activities over a period of five working days.

Additional performance-related data is presented in Figure V-2. The data show that the standard reports, simple and complex transactions, and out-bound data—other, table push-down, and system-to-system output (SSO)—account for less than 25 percent of the processing workload. The other three-fourths of the workload is caused by processing data sent to REMIS from CAMS via system-to-system input (SSI), operations overhead, and ad hoc reports using REMISTALK.

This does not appear to be a satisfactory situation. The system is overloaded and unbalanced with the current workload without considering the projected workload. It is clear that improvements to performance are necessary for the existing users. Based on the data in Figure V-2, two functions (operations and REMISTALK) appear to be candidates for performance improvements. Action was taken in December 1992 to balance the workload between HQ1 and HQ2. This resulted in a modest improvement, but the workload has increased in the meantime. Continued efforts to balance the workload between HQ1 and HQ2 offer the greatest potential in the short term to improve report

throughput and response time. It is critical that this work be funded and successful since the SSI process and report requirements will require even more HQ1 resources when GCSAS becomes operational across the fleet.

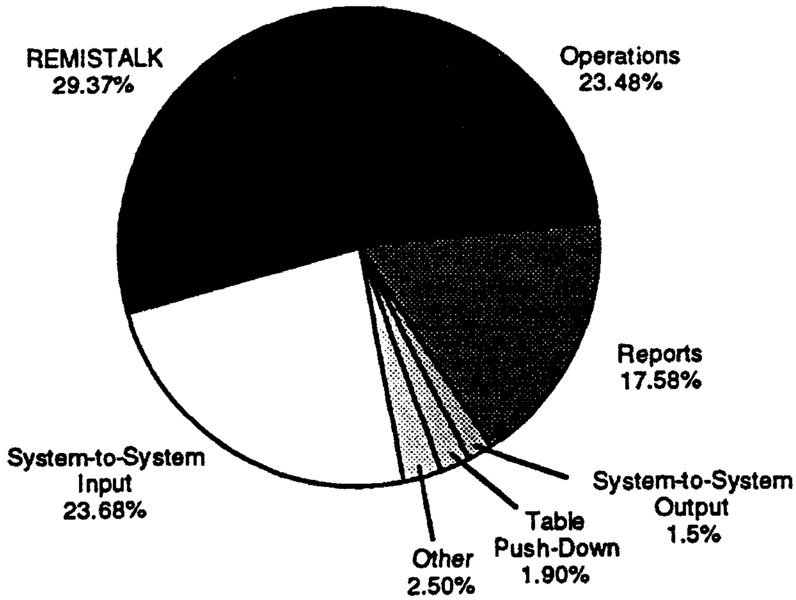


Figure V-2. Utilization of REMIS HQ1 Processor Time

If the September 1992 usage projections are realistic requirements, the performance-improvement efforts outlined in the previous paragraph will not nearly be sufficient. The projections imply that the system must be capable of handling seven or eight times the current workload. It is not clear what improvements can be made to the REMIS configuration to enable the system to support such a workload, short of substantially increasing the REMIS system computing power.

(3) **REMISTALK.** REMISTALK is a data base query generator program that enables users to create ad hoc reports directly. REMISTALK is intended to be used for those situations requiring data not available from the standard report programs. It provides a mechanism to the everyday REMIS user that allows the user to create ad hoc report requests without waiting for programming services that would otherwise be necessary to generate reports. REMISTALK offers the prospect of creating a report request and getting the data back in anywhere from six minutes to six hours, depending on the amount of data and complexity of the report. This task takes from six weeks to six months when relying on programming services.

The REMISTALK design provides for a full range of report-creation functions, including sorting, printing, sort and print break, if-then logic, calculation, summarizing, and report formatting. It employs an easy to use "pick-and-click" interface for report and query design, and provides users feedback at every step. There is a user library that may be used to build or share reports with other users, and there is a status board that provides information about the progress of the report-data-gathering activity. The user may save the ad hoc report design and reuse it or modify it for different selection criteria, thereby reducing the effort to create reports.

REMISTALK currently has two major problems. The first problem stems from the notion of a Reportable Database Area (RDA). REMISTALK is limited to obtaining data from records defined by the RDA. The reason for the RDA is to eliminate the need for (and ability of) users to "join" (a relational data base operation) existing data tables into new tables. The RDA provides pre-defined tables or views that the users may use for ad hoc reports. This saves the users time and effort, and reduces the amount of computer resources required to process the report. On the other hand, if the data a user needs is not included in the RDA, REMISTALK cannot be used successfully. Over time, if funding is made available, additional RDAs can be produced, which will make more data available to more users. In the meantime, the small number of RDAs (six) is the source of a lot of user frustration and dissatisfaction.

The second problem with REMISTALK is the amount of time it takes to provide information in response to a user's request. The average run time of a REMISTALK inquiry is roughly eight hours. REMISTALK has a propensity to use a lot of computer power and thus it is given a low scheduling priority within the REMIS central computer. This low priority is a contributor to slow user requests, but it is not the main factor. The programs executing the REMISTALK functions and obtaining the data use too much computer resources, and take too long to execute. This problem needs to be fixed. We offer the following potential solutions:

- Move the REMISTALK operation to the remote processors at the ALC locations. The processors are under-used and the move could provide relief to the central processor and provide faster service to the REMISTALK users by allowing more computer power for REMISTALK. Additional software licenses would be necessary since REMISTALK uses a proprietary program called FOCUS.
- Artificially limit the amount of time any ad hoc request may execute. This could be done by the REMISTALK software examining the request when submitted, calculating the expected run time, and if over the limit, inform the user and

reject the request. Requests that take longer than the limit could be handled by the REMIS central facility staff.

- Create a read-only data base that is used exclusively by REMISTALK and the standard reports. This version of the data base would be updated periodically (weekly, monthly) with the data received from CAMS and other sources. This action would eliminate interaction and competition for resources with other REMIS functions at the central computer system.
- Examine the design and implementation of REMISTALK for programming defects and inefficient logic to reduce the amount of computer power required to execute REMISTALK.
- Balance the existing workload and add another computer, or a faster, more powerful computer at the central system location. This "brute force" approach would not necessarily fix the underlying problems, but it would provide improved REMISTALK report responses.

Any or all of the above options require funds that are not currently in the budget for REMIS. The REMIS cost estimate prepared by the study team includes funds for examining all the options above and implementing the last two.

(4) **CAMS.** CAMS operates on the SBLC in a shared environment at over 100 bases. This evaluation is based on data obtained from the SSC at Gunter AFB. The IDA team was given data from 96 bases on the average number of daily transactions (first shift) and the average transaction response times during January and February 1993 (see Table V-4). For the most part, these transactions are simple queries and maintenance record updates

Table V-4. CAMS Average Base-Level Performance Data

Topic	Value
Average number of transactions per day	12,188
Average response time	4.56 seconds
Average number of log-ons per day	196
Percentage of SBLC use due to CAMS	44%

The average response time seen at the terminal was 6.97 seconds. Communication time accounted for 2.41 seconds, and the SBLC accounted for 4.56 seconds.

Figure V-3 provides more information. This graph shows the percentage of CAMS installations with average response times (excluding communication time) within the ranges given (1 to over 8 seconds). About 30 percent of the CAMS bases have average response

times of 3 seconds or less, and about 18 to 20 percent have average response times of greater than 5 seconds.

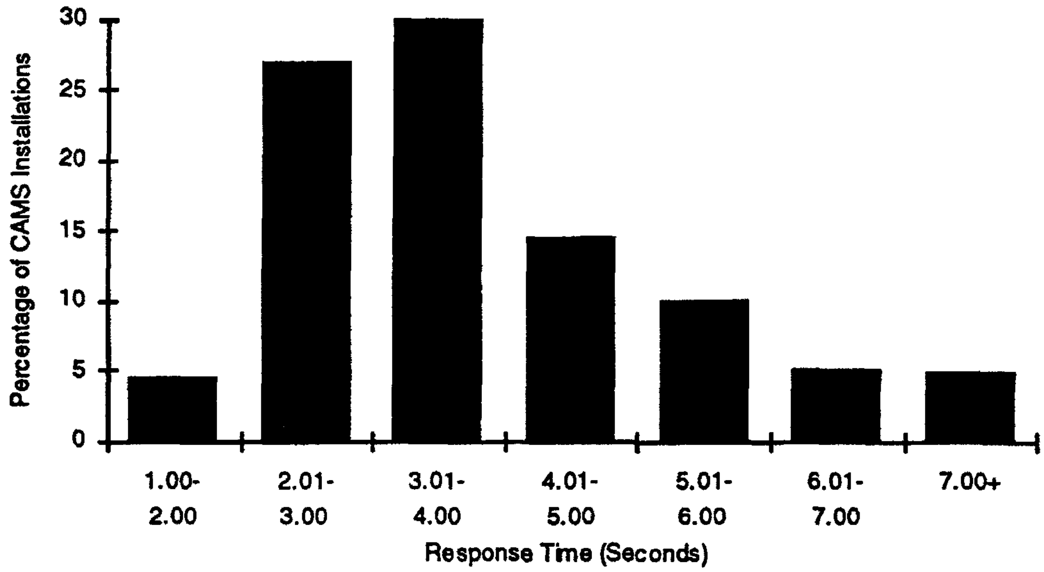


Figure V-3. Distribution of CAMS Transaction Response Times by Base

Figure V-4 shows the number of transactions per day per base, and Figure V-5 shows the response times of the same bases. There does not appear to be any relationship between the number of transactions processed (workload) and the transaction response time. In fact, the bases with a relatively low transaction workload are frequently the bases with the slowest transaction response times. Also, some bases with transaction workloads that are among the highest show fast transaction response times.

While the overall average of the CAMS transaction response times is acceptable by Air Force standards, it is apparent from these data that the response times from about 20 percent of the bases are a problem. This poor showing may be due to the differences in ADP support and management among the bases. Another possible reason for this poor performance may be that these bases do not have sufficient computing power to handle the workload. Problems with the communications equipment being overloaded or improperly used would not be reflected in this data since the data addresses the response of the central computer only.

Whatever the reasons, the current plan to regionalize the SBLC systems should alleviate the problem.

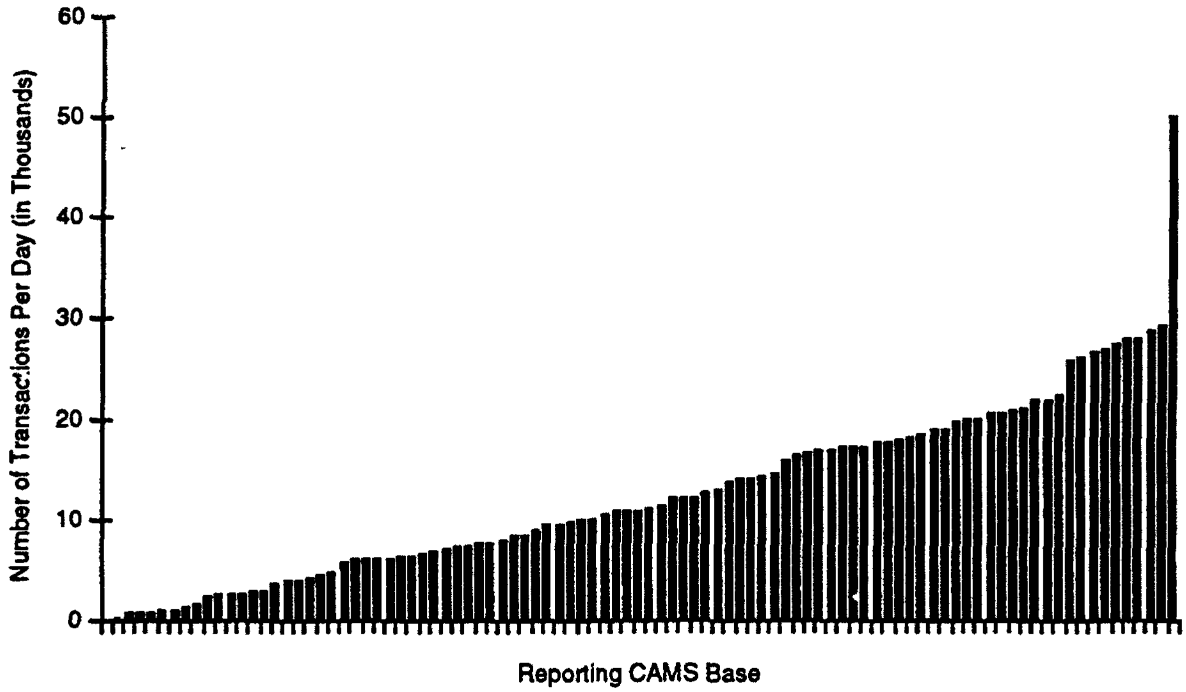


Figure V-4. Number of Daily Transactions per Base

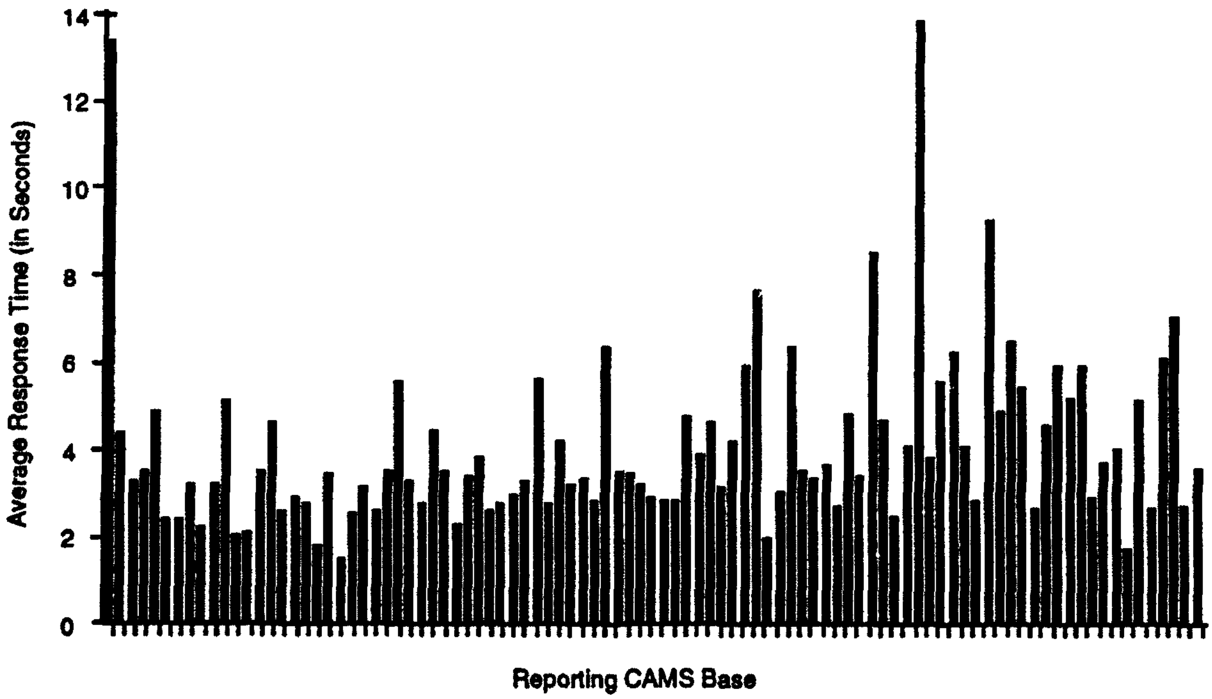


Figure V-5. Distribution of Base Transaction Response Times (Ordered by Transactions per Day)

c. System Architecture and Software Design

This section examines the way that the architecture or structure of each system affects its operational characteristics. Figures V-6 and V-7 depict the respective architectural configurations of CAMS/REMIS and TICARRS. The CAMS/REMIS configuration is shown as it will be with the implementation of the Regional Processing Centers in 1995. The TICARRS configuration is shown as it was intended to operate (with direct data entry, not entry via CAMS).

Figure V-6 shows the base-level CAMS data bases residing in the Regional Processing Center (RPC), while data are entered at the base level via the local base terminal network and the DCP. Communication with the RPC from the bases is via high-speed communication lines. CAMS sends a subset of the data base information to REMIS via Defense Data Network (DDN) lines periodically (some data each hour, other data once a day), at which point the data input processor (SSI) edits and translates the data into REMIS format and stores it in its database. If the data do not pass the edit test, they are rejected and returned to the respective CAMS base for correction. The REMIS data are contained in three modules: EIMSURS for status, utilization, inventory, and scheduling; PPS for reliability and maintainability data; and GCSAS for configuration data and TCTO management. Users at the ALC and contractors access the system for data and reports through one of five remote processing systems, which perform all the screen management and user authorizations. Weapon system configuration data, inquiries, and requests for data are sent to the central system from the remote systems, where they are processed and appropriate responses are returned.

The TICARRS architecture is shown in Figure V-7. Data are entered at the base level via the base terminals and data network. The DCPs concentrate the data for transmission over high-speed lines to the TICARRS central computer. The TICARRS software (Conversation Manager) determines the type of transaction and establishes a conversation with the users to complete the transaction. Data are edited and, if acceptable, stored in the TICARRS database. If the data do not pass the edit, the data-entry person (e.g., a flight-line technician) is notified on the spot before the transaction is completed. If the data-entry person disagrees with the edit results, the edit may be over-ridden with the approval of the supervisor in charge of the maintenance activity. Other users, not at the base level, may also obtain data and report by establishing a link through leased or dial-up lines.

Table V-5 summarizes the architectural attributes of these systems.

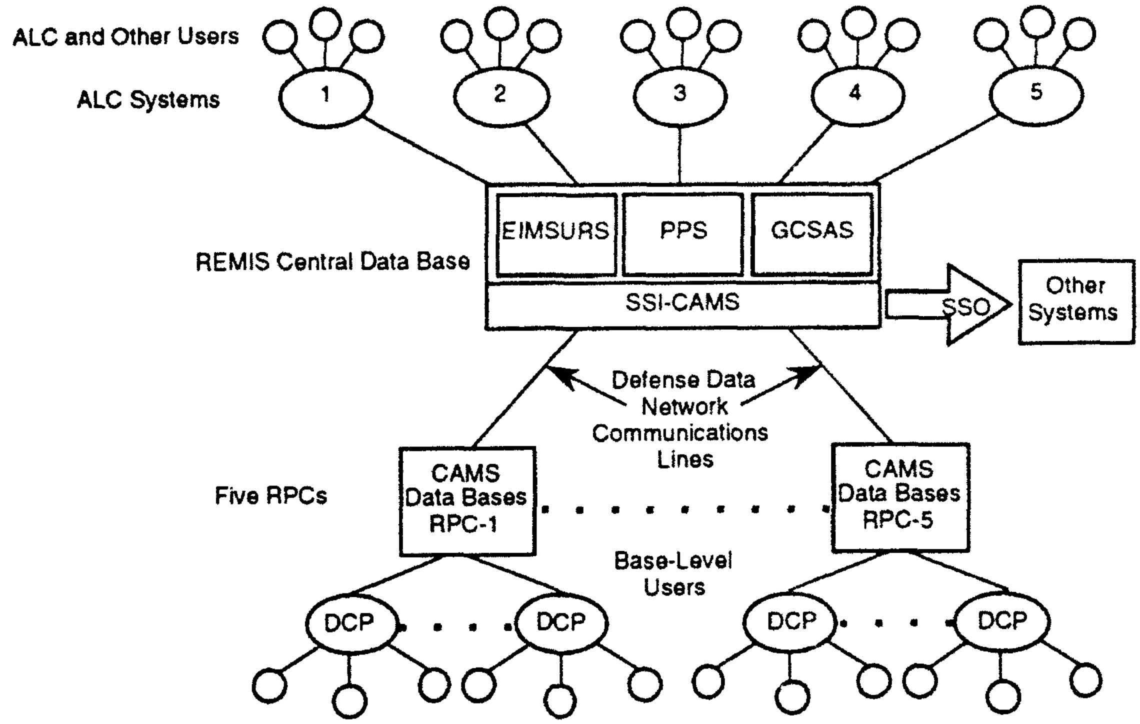


Figure V-6. CAMS/REMIS Configuration

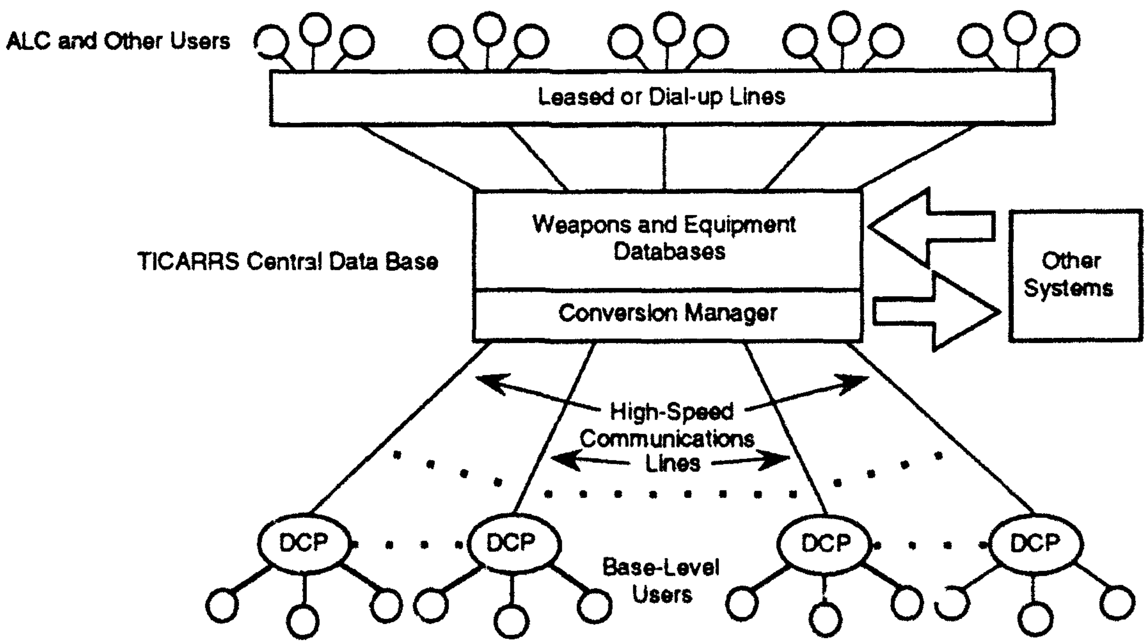


Figure V-7. TICARRS Configuration

Table V-5. System Architecture Attributes

Attribute	TICARRS	REMIS	CAMS
Number of systems	Single system	Multiple systems	Multiple systems
Shared/dedicated	Shared/dedicated	Dedicated	Shared
Data base range	Centralized: Fleet	Centralized: Fleet	Centralized: Base
Data base type	Network	Relational	Network
Data base organization	Weapon	Functional	Organizational

(1) **Number of Systems.** The requirements for management control, software tools, and operational discipline increases as the numbers of systems and system locations rise. If these requirements are not met, the effectiveness and utility of the entire system deteriorates and becomes unsatisfactory over time.

TICARRS is a single location system. There is no requirement for inter-system management controls, tools or operational controls beyond that needed for communication network management. Operational procedures, systems' servicing, system availability or performance problems are all handled at one location for one system. This reduces the number of operational and maintenance resources required to operate the system.

REMIS is a multiple location system in that it uses a six-site distributed processing system. The REMIS program development has invested in a sophisticated network and processor control center and software tools to monitor and control each of the six systems (five located at ALCs). The control center allows the REMIS operations staff to detect problems at each of the ALC-located systems and initiate remedial action. This could be thought of as a "coupled" multiple location system due to the control-center facility.

CAMS is a multiple-location system by virtue of using the SBLC systems at each of 109 bases across the country. Operational control, servicing problems, and management of the systems is the responsibility of each base ADP center. Hence, from a CAMS perspective, each base must deal with availability, performance, and data base problems in its own way, as local base conditions permit. Therefore, CAMS operational effectiveness is largely dependent on the ability, motivation, and experience of the base ADP personnel, and their execution of base-level procedures. There is no coupling of CAMS control or service in this situation. It is no surprise to find that the operational characteristics of CAMS vary significantly from base to base. (See the previous subsections on system availability and system response time and subsequent subsections on ease of use and data accuracy and completeness).

By mid-1994, CAMS will be operating at Regional Processing Centers in CONUS and, if plans are approved, in U.S. Air Force Europe and Pacific Air Force as well. The regionalization initiative has reduced the number of ADP personnel needed to operate the base-level systems, and will reduce the number of different physical locations from 107 (89 after base closures) to 7 worldwide. Although the number of physical locations will be reduced, CAMS will still be a multiple-location system under regionalization, with a separate data base for each base. Some of the operational control, servicing, and management problems should improve with the RPC. However, the base-level CAMS data base managers are a key element in the operation and management of CAMS, and they will remain at the bases to support users on site. This may leave CAMS with many of the same problems cited above.

(2) Shared/Dedicated. REMIS operates on a computer system dedicated to providing weapons systems management information. TICARRS shares a computer with other applications, but it would have a dedicated computer system if it were expanded to cover the entire Air Force. CAMS shares the SBLC with other applications at the base level, and this will continue under regionalization. While the TICARRS and REMIS operational organizations are able to focus resources on the optimum operation and services of one application, the SBLC operational organization is (properly) required to divide resources between all applications, and focus on the optimum performance and services of the SBLC system as a whole, rather than solely on CAMS. The current evidence is that may be detrimental to the smooth and satisfactory operation of CAMS at some locations.

(3) Data Base Type, Range, and Organization. These data base attributes serve only to provide a framework for briefly describing each of the three systems' data bases. They are relevant in that database design has a bearing on system performance, data base maintenance, and growth ability.

Both TICARRS and CAMS data bases are network-hierarchical types. REMIS uses a relational type of data base. Network type data bases are generally used for high-transaction-rate systems, they are complex to design and maintain, and once defined, they are difficult and time-consuming to change. Relational data bases, are not as fast, but are easier to maintain, expand, and change, and are somewhat easier to use in terms of accessing and reporting different aspects of the data base records. The key point here is that since CAMS uses the network type data base, the technical expertise of the data base manager at each base-level system must be very high to perform daily maintenance. Studies by the Air Force have shown that the data base managers generally do not have this level of expertise, which may explain some of the data completeness and accuracy problems

(discussed in a later subsection) and some of the availability problems seen at many of the bases.

The TICARRS and REMIS data bases are structured to cover the entire (world-wide) fleet of weapons systems, albeit with completely different data base organizations. The CAMS data base is designed to encompass the weapons systems assigned to the base. This is reflected in the way each of the data bases are organized. The CAMS data base is structured around the base-level organization (e.g. unit, organization, work center, people/equipment/resource). The TICARRS data base is organized around the weapon system itself. The REMIS data base is functionally organized around three major data interests as served by EIMSURS, PPS, and GCSAS.

The main effect of this aspect of data base design is that both CAMS and REMIS must be used to collect maintenance data, and provide a worldwide view of the maintenance status and history. TICARRS offers the same capability in a single centralized system. Data accuracy and completeness are affected by the CAMS data base design, in that erroneous data entries cannot be completely verified on a fleet-wide basis without the need to have REMIS check the data. This has resulted in use of a series of complex procedures involving REMIS, CAMS, CAMS data base managers, ALC personnel, and base maintenance personnel to reduce the number of erroneous transactions generated at the CAMS level and rejected at the REMIS level. When erroneous transactions are found at the REMIS level, all following data related to the erroneous record are rejected. This creates gaps in the maintenance data that must be filled by the maintenance personnel re-entering the data after the erroneous records have been corrected. Experience and data measurements indicate very clearly that this approach usually does not work in practice.

Finally, the data base design is frequently reflected in the way that the data are entered. One of the most frequent complaints by users of CAMS is the requirement to re-enter data when moving to a new screen in the same process. This occurs in TICARRS and REMIS as well. Requiring a user to re-enter data can lead to errors in the data, as well as annoyance of the user.

d. Operational Management and Control

Operational management and control involves the day-to-day operation of the computer center, making corrections to the data base when the contents are found to be in error, updating the system with the latest version or release of the software, adjusting the system scheduling/priority parameters to improve the service to the system users, scheduling regular preventive maintenance time, and instituting and executing procedures

that ensure the security and safety of the system and data. The operations personnel are required to have total knowledge of the system and expertise on the powerful software tools used to manage and control the system.

The skills and experience necessary to manage and implement operational control are not easily or quickly gained. The nature of the systems being used to collect and maintain the weapon systems data demands highly skilled and experienced operations personnel. All three systems, CAMS, REMIS, and TICARRS have essentially the same requirements for operational personnel in terms of skill and experience. TICARRS and REMIS have the advantage of only having to establish a single, central staff of people who can focus full-time on the weapons maintenance information system. CAMS, on the other hand, works under the control of the operations personnel at each SBLC or RPC, where there may be less emphasis on the weapon maintenance information system than there would be in a single application environment.

For example, the data base administrators at the SBLC or RPCs are responsible for balancing the allocation of disk space to satisfy all applications, not just CAMS, thereby allowing for a less than optimal situation for CAMS. Another example of how focus may be diluted is illustrated in reports by CAMS development personnel that the software releases sent out with new features and repairs to problems are sometimes not installed on the SBLC systems for up to 10 months after they are available.

The CAMS data base managers (DBMs) have an important role in the operation of CAMS. They are not part of the regionalization initiative and will remain at the bases. The DBMs are responsible to support the CAMS users at the base, trouble shoot software problems, and repair data base problems that deal with the logical structure of the data base. A survey conducted by the CAMS PMO determined that the majority of DBMs had less than three years experience, 28 percent had no formal training and no expertise on using operations software tools. It is clear from the systems availability data and the system response time data that, since some systems are operating well and many are experiencing poor availability and performance, the operational management of CAMS must be held accountable for part of the system behavior.

The effort to regionalize the SBLC system will reduce the need for so many skilled people. Plans call for consolidation of 12 to 15 systems in each region. While there is an opportunity to improve the operational management of the systems at the regional centers, the support burden on the base-level DBMs will not diminish. They will be required to:

- provide data base surveillance,

- fulfill user requests for background and special reports,
- provide data base security,
- delete histories,
- provide minor data base maintenance,
- monitor new releases of CAMS,
- coordinate between affected units on system downtime, and
- provide detailed system problem resolution.

A proposal by the CAMS PMO to establish a CAMS data base support function at Gunter SSC will provide needed expertise at a central location that can be shared by all bases. In addition, a CAMS manager would be established at each base to conduct CAMS user training, provide end-user problem liaison and initiate user-suggested CAMS improvements. If implemented, this proposal could allow the data base managers to focus their attention on the operations and the resolution of problems that arise at the base level within the current staffing levels (three to four per base).

By comparison, within the TICARRS central-site operation, most of these functions are performed at the central site, and do not require the same amount of support from site representatives as is required with CAMS. The TICARRS site representative normally undertakes the following:

- developing and conducting on-going end-user training,
- providing end-user problem resolution,
- processing requests for functional enhancements, and
- processing user requests for background and special reports.

There will be one site representative per base and two additional representatives per base at each Air Logistics Center, consistent with historical experience with direct-entry TICARRS.

e. Continuity of Operation

The institution and execution of procedures that ensure the security and safety of the system and data are an extremely important aspect of operational management and control. Continuity of operation in the event of a disaster that prevents the operation of the computer center is of particular interest. The Air Force is dependent on the weapons management information system to provide data regarding the readiness of aircraft to fly. Therefore, the

weapons information management system must have a back-up plan to continue operations in the event of the destruction of the computer(s) and related equipment.

Each of the systems being analyzed have alternative plans and back-up procedures that are adequate in the event of equipment breakdown, communication failures, power failures, and other serious, but manageable, outages. However, none of these procedures are of benefit if the entire computer system becomes inoperative as the result of an explosion, uncontrollable fire, and so on, unlikely as such as event may be. A back-up plan for operation in case of such an event requires that the maintenance information management system operate on a compatible computer system in a location remote from and unaffected by the disaster. There must be a capability to switch communication lines to the back-up computer location and there must be a recent copy of the data base, programs, and operating procedures available to start and run the system.

TICARRS does not have a disaster back-up capability in place. Because TICARRS is fed data by CAMS, a back-up capability is not necessary. CAMS would continue to collect the data, and aircraft at the squadron level would still have sufficient maintenance information allowing them to fly. Should TICARRS become the standard maintenance information management system, CAMS would no longer be used to collect the maintenance data, and a TICARRS back-up capability would be required. DRC has proposed a contract with Dataguard Recovery Services to provide such a capability. For a monthly fee, Data Recovery Services would provide TICARRS with access to an off-site (Loiusville, Kentucky) compatible computer system and communication facilities in the event of a disaster outage at the TICARRS system in Andover, Massachusetts. The TICARRS data base and programs would be saved every 24 hours (more frequently if appropriate) and a copy stored off-site. Should a disaster occur, the off-site copy of the system and data base would be taken to Louisville and installed on the Bull system there. The communication lines feeding TICARRS at Andover would be switched to the Louisville site, and TICARRS would operate there until permanent facilities could be established. The proposed contract gives access to TICARRS for test time, so that the disaster procedures may be exercised in practice drills.

Since REMIS is not used to directly collect maintenance data (such data is provided by other systems like CAMS), a disastrous event knocking out the entire central system would not be as critical as it would be for CAMS (or TICARRS). The REMIS disaster recovery plan entails installing the REMIS data base and programs (saved daily and stored off site) at the REMIS satellite ALC location at Tinker AFB. The computer system there has five processors, and would be expanded, as appropriate, to include sufficient power to at

least collect data from CAMS and other key maintenance sources to provide the Air Force with a fleet-wide view of aircraft inventory and status.

The disaster recovery plan for CAMS is included in the RPC disaster recovery plan. As with the other two systems, the CAMS data base and programs are saved daily and stored off-site. All of the RPC installations are installed with 25 percent more equipment capacity than needed to service the bases they support. In the event of a disaster at one of the RPCs (that is, the entire RPC becomes inoperable), the back-up data bases and programs would be taken to the remaining RPCs and installed. The base-level communication lines would be switched to the RPC handling their workload. Satellite communications would be used to handle the U.S. Air Force Europe and Pacific Air Force bases if their RPC is out of commission.

Each of the systems have or have proposed a disaster recovery plan that would provide continuity of service. Evaluation of the plans from three perspectives follows:

- Extent of support. None of the three plans permit the maintenance information management system to operate without some degradation of service. The TICARRS proposal would require the bases to use the system on a scheduled basis, for example, according to geographic location to spread out the workload, and limit or eliminate standard reporting for the duration of the emergency. The RPC/CAMS plan would degrade each of the remaining RPCs such that service would be reduced and/or deferred during the emergency. The REMIS plan would also limit service to accepting maintenance data, and severely restricting or eliminating the generation of standard and REMISTALK reports.
- Effectiveness of support. A key ingredient in providing support is the availability of technical personnel to operate and manage the system. If a disaster struck the operational centers of these systems, the people operating and managing the systems could be unable to continue due to injury. Both TICARRS and REMIS are centrally managed by a relatively small team of operational staff and would be hard-pressed to replace them. Other similarly skilled personnel in the organizations could be used, but they would not likely be familiar with the operation of the respective systems. Since CAMS would be installed in other RPCs, which were also operating CAMS, there would be little or no skill or training problem in supporting the bases from an operational viewpoint.
- Execution of support. Of the three plans only the CAMS plan at the RPCs has been tested. TICARRS has not had the need or opportunity to do so, and REMIS, not yet fully operational, has not yet taken the opportunity to conduct such a test.

f. Summary

The purpose of examining the system and technology related to operating characteristics is to understand the relative strengths and weaknesses of each system beyond functional capability or scope of service. The results of this analysis are an important factor in determining the effort and expenditures that must be applied to each system to provide a satisfactory weapons maintenance information system, regardless of which system is ultimately used.

In addition to the issues of requiring additional functional capability and supporting additional weapons and equipment, it will be necessary for the TICARRS central computer system to be significantly expanded. If TICARRS is to undertake the transaction workload currently processed by CAMS, it will need to be about four times more powerful than the currently installed system at Andover, Massachusetts. This increase would permit TICARRS to handle all the CAMS transactions and data reporting functions provided by REMIS. The system availability and performance exhibited by the TICARRS system are adequate, as is the operational management control. It will be necessary for the TICARRS system to maintain the same level of performance if selected to support all the weapons, bases, and users. Finally, a back-up disaster recovery process would need to be installed to ensure continuity of service.

Two key system technology and performance issues affect our evaluation of REMIS. The first is the system performance of REMIS. While the simple transaction response time is adequate, effort must be expended to balance the central computer workload to provide better turnaround time for those users requesting standard and REMISTALK reports. In addition, the programs that provide operations support and those that process input from CAMS (SSI) must be examined to see if the amount of computer resources used can be reduced. Ultimately, additional computing power will be necessary to handle the full workload expected by REMIS. The second issue, related to the first, is that the standard report capability of REMIS must be extended, and the REMISTALK program must be expanded to allow a broader scope of data to be included in its reporting capability. While extending the scope of REMISTALK is not a technical challenge in itself, doing so without exposing the system to more performance problems will require significant investment in analysis and design at the system level. The REMIS disaster back-up plan must be tested to verify the ability of REMIS to support the Air Force under disaster conditions.

CAMS suffers from poor availability and poor transaction response time at many bases. Unfortunately, it is unclear how much of the problem is tied to the CAMS software,

how much is due to operational difficulties, and how much to communication system problems. The evidence indicates that CAMS has good performance and good availability at a few bases, which leads to the conclusion that without top-notch ADP and data base manager support, CAMS may continue to see the same level of performance and availability. The move to RPCs will tend to improve operational control and discipline. CAMS data base managers will need to remain at the bases as planned, and the institution of a CAMS representative will be helpful. The reliability of CAMS software needs to be examined to ensure it is not the basis of CAMS availability or performance problems, since the RPC experience to date has shown that the RPC computer availability is not a significant problem. It is possible that the few bases with good performance and availability are not seeing the same problems as the majority of the bases. This must be an ongoing effort of the CAMS development and maintenance staff.

2. Data Integrity and Security

A maintenance data system requires procedures to ensure that only authorized persons can enter or change data. According to the Air Force, CAMS meets the requirements for a Trusted Security Level C2. REMIS is also required to meet the Level C2 requirements, according to its current operational requirements document. If TICARRS were to become the standard Air Force system, it would presumably be required to meet the same requirements.

The SBLC system used by CAMS is vulnerable to tampering. A June 1992 Air Force Audit Agency report concluded that security features were not adequate to protect the SBLC communications process, the SBLC network, the SBLC data base, and remote terminals. The report stated, "under carefully controlled conditions, we were able to access the SBLC communications processors at 22 of 24 bases tested via the Defense Data Network without detection and without using an SBLC user identification code or password." Inadequate control of dial-up access could lead to "overstating the quantity of parts actually on hand" which "could affect a base's day-to-day ability to meet aircraft maintenance schedules." Corrective actions are under way. The Air Force Audit Agency stated: "The corrective actions taken and planned are responsive to the issues and recommendations in this report." Regionalization will mean fewer sites to secure, but will increase the importance of secure communications and remote terminals.

REMIS security procedures are also a concern. While a password is required in order to input configuration data, once a person gets access to the system, he or she can enter configuration data on any system. For example, a KC-135 expert could alter the

configuration for the C-141. While REMIS developers are aware of this difficulty, they have concluded that it is too difficult to resolve within the current REMIS architecture and cost constraints.

REMIS does not currently meet Level C2 requirements, because its Tandem platform did not have the appropriate security product available. REMIS is currently using a software called ONGUARD from Computer Associates. Tandem has recently released a package called SAFEGUARD that meets Level C2 requirements. Litton is working to determine the cost of upgrading to SAFEGUARD, but the required resources and costs were not available for this study.

TICARRS has not been officially certified as meeting the requirements for Trusted Security Level C2, but its architecture seems easily adaptable to meet the requirements. The software currently has the process controls required to limit access and capability by authorized users. The transaction journals provide an audit trail of all activity against the data base via on-line conversations. Also, whenever a user creates or modifies a record, the affected record contains the operator identification (ID) plus the date and time of the action. When standard queries are executed, a data base record is written recording query parameters plus the operator identification. All access and executions initiated via the Bull Timesharing Subsystem are also traceable. TICARRS has the capability to set the time-out parameter (time after which the system disconnects if the terminal is not touched) to any level required.

Assigning individual operator identifications would require some modification to the operator identification-generation program. When new units are activated under TICARRS today, the group operator IDs are automatically generated from the organization structure. That program would require modification to generate an operator ID for each person loaded to TICARRS under the Personnel Management Conversation. Individuals would be given a default set of permissions based on their organization and duty Air Force Specialty Code. Current TICARRS software already provides for the delivery and maintenance of the operator IDs. The operator ID data field provides for the generation of over 60 million passwords using just alpha and numeric characters, so no changes are required in the data field size. The number of personnel accessing TICARRS from locations other than units is usually small, and many of them already have an individual operator ID assigned. Approximately 100 labor hours would be required to modify the existing operator ID-generation program.

3. Ease of Use

Many characteristics play a role in determining the ease of use of an information system. The following are among them:

- difficulty in learning to effectively use the system,
- adequacy of training, including manuals and documentation,
- presence and type of help facilities,
- presence of error checking, completeness of checking, and usefulness of error messages,
- need for multiple data entry,
- ease of obtaining reports, both standard and ad hoc,
- consistency of the user interface,
- ability to input and output data easily and quickly, and
- ability to modify data.

We used three primary sources of information to address the issue of ease of use for CAMS/REMIS and TICARRS:

(1) IDA team members' observations and discussions with users,

(2) responses to a survey during the Operational Assessment of TICARRS 92, and

(3) answers to structured questions posed to the REMIS developers and to the F-15 SPO (which uses TICARRS).

a. Observations of and Discussions With Users

Throughout the course of this study effort, the IDA team made deliberate and extensive observations on the operations of CAMS, REMIS, and TICARRS at base, depot, MAJCOM, and SPO levels.

Base-level observations of users (Langley, Hill, Holloman, and Seymour Johnson) provided mixed opinions about the two information systems—not a surprise since bases have some latitude in organizing and implementing maintenance policies and procedures. Our observations at the bases provided the following information:

- CAMS is considered slow and difficult to use, requiring more screens than TICARRS for many functions,
- CAMS served the debrief function adequately,
- engine management was completely satisfied with CAMS at Langley AFB,
- training and motivation for CAMS is insufficient,

- CAMS was sufficient for scheduling and management,
- REMISTALK is slow in retrieving information, and some users were not satisfied with the level of training,
- TICARRS was easier to use than CAMS,
- TICARRS requires DRC support for some minor changes to the system,
- some backshop personnel thought TICARRS required too many screens to retrieve information, relative to CAMS, and
- depot maintenance personnel found that TICARRS conveniently provided the necessary information to support the two-level maintenance test at Ogden.

Our observations at one MAJCOM (Air Combat Command) yielded the following information:

- interface problems between CAMS and REMIS are serious in the areas of status, inventory, and utilization,
- REMIS has problems downloading data,
- REMIS is slow,
- REMIS cannot easily provide raw data for analysis, and
- REMIS adequately supports the logistics community.

No other MAJCOMS were solicited for information on the scale of ACC.

ALCs seem to have success using REMIS and, since few of their requirements are extremely time-sensitive, some delays in getting information are not critical. In general personnel at the ALCs had the following to say:

- REMIS is user-friendly and improving over time,
- REMIS handles communications-electronics and space equipment adequately,
- REMIS might be losing 40%-50% of the data it should have, and
- training on REMIS is poor.

The SPOs have an easier time accessing and using TICARRS than REMIS. Contractors have the following opinions:

- REMIS suffers from poor access, poor training, and inability to retrieve data easily and quickly,
- They prefer working with raw tapes of product performance data,
- TICARRS's retrieval of narratives and other select information is relatively easy,
- They get better support for TICARRS than for REMIS.

b. Formal Survey Taken at Operational Assessment of TICARRS 92

During the Operational Assessment of TICARRS 92, a number of questions were asked of the Seymour Johnson personnel about the ease of use of CAMS, of TICARRS, and of TICARRS compared to CAMS. Responses were categorized by generic work center (flight line, backshop, staff) and paygrade (E-1 to E-3, E-4 to E-5, E-6 and above). The specific measurement criteria were ease of use, ability to input easily, ability to output easily, ability to modify data, usefulness of training, usefulness of manuals and documentation, ability to input quickly, and ability to output quickly.

Tables V-6 and V-7 show the percentage of respondents who were either satisfied or very satisfied with an aspect of system operation (aggregated together as satisfied) as a percentage of those who had an opinion (including those who responded mixed/neither). The tables also show the percentage who were either dissatisfied or very dissatisfied (aggregated together as dissatisfied).

Table V-6 shows the responses for the pre-assessme... survey of CAMS users. Between 23 and 4` percent of the of the flight-line respondents were satisfied with these features, while between 33 and 50 percent were dissatisfied. In the backshops, satisfaction ranged from 32 to 46 percent and dissatisfaction from 23 to 34 percent. Staff satisfaction ranged from 29 to 60 percent and dissatisfaction from 18 to 40 percent. For all paygrades and work centers combined, those satisfied or very satisfied ranged from 32 to 45 percent; those dissatisfied or very dissatisfied ranged from 26 to 41 percent.

A large number of respondents (30 percent for overall ease of use) gave responses that indicated indifference to the ease of use of the information system.

Although paygrade distinctions are not shown in the table, lower pay grade personnel had satisfaction levels between 35 and 44 percent. E-4s and E-5s ranged from 30 to 48 percent. E-6 and above ranged from 27 to 44 percent.

While there were variations by work area and pay grade, the ability to generate output was the most liked feature of CAMS. Speed of input and the ability to change data were the most disliked.

Table V-7 displays users' opinions about the ease of use of TICARRS, derived from responses to a survey taken during the sixth week of the Operational Assessment.

Table V-6. Results of Pre-Assessment Survey of CAMS Users

Criteria	Response	Flight line	Backshop	Staff	All
Ease of use	satisfied	37%	42%	60%	42%
	dissatisfied	35%	24%	23%	28%
Ability to Input Easily	satisfied	32%	44%	60%	41%
	dissatisfied	40%	25%	23%	31%
Ability to Output Easily	satisfied	42%	46%	52%	45%
	dissatisfied	33%	23%	18%	26%
Ability to Modify Data	satisfied	23%	35%	42%	30%
	dissatisfied	50%	33%	40%	41%
Usefulness of Training	satisfied	27%	38%	47%	34%
	dissatisfied	34%	28%	28%	31%
Usefulness of Manuals and Documentation	satisfied	29%	32%	42%	32%
	dissatisfied	40%	30%	30%	34%
Ability to Input Quickly	satisfied	27%	40%	43%	35%
	dissatisfied	50%	33%	30%	40%
Ability to Output Quickly	satisfied	30%	35%	29%	32%
	dissatisfied	45%	34%	37%	39%

Table V-7. Opinions Concerning TICARRS in Six-Week Survey

Criteria	Response	Flight line	Backshop	Staff	All
Ease of use	satisfied	47%	37%	41%	41%
	dissatisfied	21%	33%	26%	28%
Ability to Input Easily	satisfied	47%	37%	38%	41%
	dissatisfied	25%	33%	25%	29%
Ability to Output Easily	satisfied	38%	28%	24%	31%
	dissatisfied	31%	40%	37%	37%
Ability to Modify Data	satisfied	35%	26%	31%	30%
	dissatisfied	32%	40%	33%	36%
Usefulness of Training	satisfied	29%	27%	22%	27%
	dissatisfied	29%	40%	38%	36%
Usefulness of Manuals and Documentation	satisfied	32%	29%	17%	29%
	dissatisfied	27%	33%	26%	30%
Ability to Input Quickly	satisfied	45%	34%	31%	38%
	dissatisfied	29%	33%	33%	31%
Ability to Output Quickly	satisfied	42%	25%	21%	31%
	dissatisfied	32%	39%	41%	37%

A comparison of Tables V-6 and V-7 reveals that:

- Flight-line personnel were generally more satisfied with TICARRS in the ease-of-use categories while the backshops were consistently less satisfied with TICARRS. Staff was decidedly less satisfied with TICARRS.
- CAMS was preferred for ability to output easily and usefulness of training, while TICARRS was preferred for ability to input quickly. Most other measures showed mixed results.
- Again, there was a large percentage of respondents who are indifferent about these systems.
- Overall satisfaction with the two systems regarding ease of use seems remarkably similar. Of the respondents, 42 percent were satisfied with CAMS, and 28 percent were dissatisfied; 41 percent were satisfied with TICARRS, and 28 percent dissatisfied.

Comparison of survey results taken six weeks apart may not tell the whole story. People's impressions of CAMS may have been changed by their use of TICARRS. In order to get a clearer picture of attitudes at the end of the Operational Assessment, respondents were asked to directly compare TICARRS and CAMS. People were asked which system they preferred regarding the same eight ease-of-use categories. Their responses are tabulated in Table V-8.

Table V-8 shows a mild preference for CAMS. There is variation by work center. Flight-line personnel preferred TICARRS for overall ease of use by 40 percent to 30 percent though higher percentages preferred some specific aspects of CAMS than TICARRS. High paygrade flight-line personnel (not shown in the table) preferred TICARRS for overall ease of use by better than two to one. Backshop and staff personnel showed a general preference for CAMS.

Aggregating over all work centers and paygrades, CAMS was preferred by 39 percent while TICARRS was preferred by 31 percent. Thirty percent had no preference.

One of the consistent trends throughout the surveys is the large number of respondents who had no preference for either system. These values ranged from about 20 percent to over 50 percent in some cases.

It is worth noting that TICARRS was favored by more people during the fourth week of the Operational Assessment than during the sixth week. This is demonstrated in Table V-9. During the fourth week, TICARRS was preferred to CAMS among survey respondents for ease of use by 41 percent to 28 percent. There was a particularly marked

difference in the responses of backshop personnel, who favored TICARRS 40 percent to 31 for ease of use in week four. During week six they favored CAMS by 44 percent to 26.

Table V-8. Comparison of CAMS and TICARRS in Sixth-Week Survey

Criteria	Response	Flight line	Backshop	Staff	All
Ease of use	CAMS preferred	30%	44%	39%	39%
	TICARRS preferred	40%	26%	23%	31%
Ability to Input Easily	CAMS preferred	34%	39%	29%	36%
	TICARRS preferred	38%	27%	33%	32%
Ability to Output Easily	CAMS preferred	38%	47%	47%	44%
	TICARRS preferred	34%	20%	19%	25%
Ability to Modify Data	CAMS preferred	37%	45%	30%	40%
	TICARRS preferred	34%	20%	34%	26%
Usefulness of Training	CAMS preferred	29%	38%	37%	35%
	TICARRS preferred	24%	22%	17%	22%
Usefulness of Manuals and Documentation	CAMS preferred	26%	32%	33%	30%
	TICARRS preferred	30%	28%	16%	27%
Ability to Input Quickly	CAMS preferred	32%	38%	36%	36%
	TICARRS preferred	37%	30%	28%	32%
Ability to Output Quickly	CAMS preferred	34%	42%	40%	39%
	TICARRS preferred	33%	23%	17%	26%

Table V-9. Comparison of CAMS and TICARRS in Fourth-Week Survey

Criteria	Response	Flight line	Backshop	Staff	All
Ease of use	CAMS preferred	24%	31%	34%	28%
	TICARRS preferred	47%	40%	24%	41%
Ability to Input Easily	CAMS preferred	23%	27%	38%	26%
	TICARRS preferred	48%	40%	28%	43%
Ability to Output Easily	CAMS preferred	26%	37%	39%	32%
	TICARRS preferred	42%	28%	19%	34%
Ability to Modify Data	CAMS preferred	30%	35%	41%	33%
	TICARRS preferred	41%	29%	31%	35%
Usefulness of Training	CAMS preferred	25%	24%	31%	26%
	TICARRS preferred	35%	28%	16%	30%
Usefulness of Manuals and Documentation	CAMS preferred	20%	23%	24%	22%
	TICARRS preferred	41%	35%	29%	37%
Ability to Input Quickly	CAMS preferred	25%	29%	33%	27%
	TICARRS preferred	44%	37%	27%	39%
Ability to Output Quickly	CAMS preferred	26%	37%	43%	32%
	TICARRS preferred	40%	29%	23%	34%

At least five factors may have influenced the apparent shift away from TICARRS between week four and week six:

- Many of DRC's support personnel were removed from the base after the fourth week. Without the extra help, users' opinions of TICARRS may have suffered. (On the other hand, no overwhelming demand for the service of the remaining DRC representatives was observed during the last two weeks.)
- The 4th Wing was undergoing a surge exercise during the sixth week. The extra burden of using a still relatively unfamiliar system in a stressful environment may have weighed against TICARRS.
- Wing personnel may have been less serious about the Operational Assessment during the sixth week. They knew they were going to get CAMS back very soon. Perhaps the desire to get the whole thing over with colored their attitudes toward TICARRS.
- The fourth-week survey had a better response rate than the sixth-week survey: 1,055 people responded to the former (out of a relevant wing population of 1,322) and 751 responded to the latter. The fourth-week survey results may be more representative of the entire wing's opinions.
- Upon further reflection, some users may have decided that CAMS was easier to use.

On balance, it is probably best to view the Operational Assessment of TICARRS 92 as showing no marked preference for either system with respect to ease of use. (Only a slight preference for CAMS was shown at the end of the assessment.) The fourth-week survey favored TICARRS and the sixth-week survey, CAMS. Some groups of users found TICARRS more user-friendly, others preferred CAMS, many were indifferent.

It should be remembered that some of the apparent strengths of TICARRS could not be well-appreciated during the Operational Assessment. Its ability to keep track of aircraft configuration information was compromised by the inability to load comprehensive historical data from CAMS. Some of this was CAMS's fault and some was not. The incompleteness of the historical data also may have made TICARRS appear less useful (and less user-friendly) to users of the data at the wing level than it would have looked after more extensive operation (which would have populated the data base).

Of course, many of the ultimate users of maintenance information do not reside at the wing. We are really interested in comparing the user-friendliness of TICARRS with that of CAMS/REMIS. The Operational Assessment only addressed the comparison between TICARRS and CAMS.

c. Response to Structured Questions

IDA requested the same information about the number of maintenance actions, mean time between maintenance actions, and other product performance data by aircraft type, by work unit code (WUC), and by part number from both the REMIS developer and from a TICARRS user (the F-15 SPO). The idea was to compare the ease of use and functionality of the two systems. TICARRS was able to provide all the requested information in a straightforward way. On the other hand, the REMIS experts were often unable to provide the desired information, delivering information on different aircraft or for different time periods than the ones addressed in the request.

In addition, standard REMIS queries were sometimes unable to provide summary information without a great deal of unrequested detail. The only way to avoid the detail was to use the more time-consuming mechanism of REMISTALK.

d. Conclusions

Despite some strong complaints about the ease of use of CAMS by wing-level personnel, the Operational Assessment of TICARRS 92 did not show TICARRS to be consistently easier to use for such users. Ease of use is probably best considered roughly equal at the wing level.

Overall, when we looked beyond the wing level, we found greater satisfaction with the ease of use of TICARRS than with REMIS. While there were instances of satisfaction with the ease of use of REMIS at the depot level, there were other instances of dissatisfaction. MAJCOM personnel, weapon system SPOs, and contractor personnel indicated preferences for TICARRS.

D. DATA ACCURACY AND COMPLETENESS

This section discusses the accuracy of Air Force maintenance data, available in CAMS/REMIS and TICARRS. As currently operated, the systems are interdependent in many respects. For example, any inaccurate CAMS data will be fed to both REMIS and TICARRS (as well as other systems), leading to complaints of inaccurate data from these systems. For TICARRS, there exists some information concerning data accuracy of the TICARRS direct-entry system (which would become standard if TICARRS became the basic Air Force information system).

It is not possible to compare the output of the two systems with an independent authoritative source of accurate data—the systems are designed, in most cases, to *be* the

authoritative source. However, we examined evidence on the performance of each of the systems relative to data accuracy and validity. We included information we gathered and information provided to us by users and developers of the systems.

It is easier to gather evidence on data accuracy and validity for CAMS/REMIS, since it operates as the Air Force's standard maintenance data system, than it is for TICARRS. The data are being loaded and processed in CAMS/REMIS, while TICARRS currently accepts data through CAMS for two weapon systems, the F-15 and F-16. One limited body of evidence for TICARRS comes from the Operational Assessment at Seymour Johnson AFB. Other information pertaining to the accuracy of TICARRS data dates from the period when TICARRS was being fed directly by users.

Information on the accuracy and validity of data in the maintenance data systems was derived from multiple sources. While there is significant anecdotal evidence to support problems in data accuracy with these systems, we have tried to limit our assessment to cases where: (1) the problem is clearly visible and significant and (2) there is empirical information to support our assessment. In the subsections that follow we first discuss CAMS/REMIS, then we cover TICARRS, providing information comparing data accuracy under TICARRS direct-entry to CAMS. We next address data integrity and security under all three systems. Finally, we summarize our assessment of the systems.

1. CAMS/REMIS

As was noted in the discussion of data base type, range, and organization, data accuracy and validity are affected by the CAMS/REMIS system architectures and data base designs and interfaces. Gaps are created in the maintenance data that must be filled by personnel re-entering the data. Experience indicates that they often do not re-enter it.

It should be noted that some of the REMIS-reject problem is not intrinsic to the system architecture, but rather follows from the Air Force's decision to relax the stringency with which CAMS edits entries without relaxing the stringency of REMIS edits. Simple data-entry errors are not picked up by CAMS, but are flagged by REMIS. This generates the same kinds of gaps in the data base already described.

a. RECFU II and Its Effect on Data Accuracy

Altering software to fix problems or provide new capabilities can cause new errors to arise in other areas. A recent example is the RECFU II release designed to allow CAMS to send hourly updates to the EIMSURS portion of REMIS via DDN rather than daily updates through Autodin. The release had defects that involved incorrect editing and

resulted in data rejects by EIMSURS/REMIS. The data rejects then caused more rejects of records that were based on the ones rejected, leading to missing data. For a number of reasons, these data were not corrected by CAMS users; therefore, the status, inventory, and utilization records had gaps.

EIMSURS was also rounding flying hours differently from CAMS. This aggravated another problem, the issue of gain/loss data when aircraft transfer or when parts are in/out of the depot. The receiving group would record a different time of ownership than the sending group, creating an error condition since the times did not match. Of course, the error condition caused any subsequent records to be rejected until the time issue was resolved, resulting in more data gaps. ACC personnel reported inaccurate data being drawn from EIMSURS. Litton reported that the problem has been corrected.

Finally, there is an issue of incorrect data in the interface between CAMS and REMIS which caused more rejects by REMIS. Several steps have been taken to remedy this situation. First, the defects in RECFU II are being fixed and tested. Second, some of the edits have been changed so that the record is not rejected, but the data items with inconsistencies are flagged to warn future users. In addition, the MAJCOMS have been given the ability to review and correct status, inventory, and utilization records if the reporting bases do not do so. Finally, the REMIS PMO is directing a manual loading of base-level CAMS data to force CAMS and REMIS to match. The REMIS data back to November 1992 are being wiped out, and CAMS data are being entered manually. The PMO reported that this activity was completed on schedule in June 1993.

Corrective actions for repair of RECFU II address some of the problems with the interface between CAMS and REMIS, but they do not address the basic problem of incorrect input from the CAMS user. Instead, REMIS will have to rely on the CAMS user (or, more likely, the data base manager) or the technician at the Air Logistics Center to correct errors after they show up in REMIS. If this process does not work, the Major Commands can change the data in REMIS, but these changes are not passed back to CAMS. The Major Commands have agreed to use the manual correction capability in a minimal way, according to the REMIS PMO. It is likely that the problem will eventually recur, unless the CAMS users go back and fix their data, which they historically have not done. It is our assessment that the regionalization of the computer systems may make this worse, since it involves a large reduction in the number of data base managers, and the remaining data base managers may have less time to correct CAMS errors.

b. Data Accuracy in CAMS—Engines

It is possible :o achieve accuracy in CAMS with sufficient time, effort, and management attention, as demonstrated by the following example. Engine components are critical for safety of flight, and AFR 400-1 and ACC 66-5 require a formal reconciliation of CAMS and CEMS engine data every six months for every base. First, the base data base manager does a delete history run so that old parts removed from the engine and shipped elsewhere do not show up as uninstalled. This cleans the data base. The data base manager then runs a backup or mirror image of the data base at a specified time. The CAMS tape is sent to Tinker AFB by express courier. Tinker personnel conduct the comparison and send the base a report of the comparison, indicating where in CAMS corrections need to be made. For major modules of the engine (1534 reportable) and serially-tracked items (D042 reportable) that are reported in CAMS and sent to CEMS, the error rate is generally less than 0.5 percent.

c. Coronet Deuce Experience

According to information collected during a portion of Coronet Deuce, the Air Forces' two-level maintenance test, there are times when not all maintenance activities have been processed through CAMS into the central data bases of REMIS and TICARRS. As indicated in Table V-10, one Coronet Deuce analyst found that, during a two-week period, 49 of the 170 LRUs (29 percent) shipped to the depot were not recorded as unrepairable at the base level in the central data base. The source of the data was TICARRS, which obtained its base-level data from CAMS.

Table V-10. Missing CAMS Information on Not-Repairable-This-Station Actions During Coronet Deuce

Base	LRUs Shipped	LRUs with No NRTS[a] Action in Data Base
Hill	14	5
Shaw	45	12
Richmond	9	1
Ramstein	29	2
Eielson	6	2
Buckley	7	6
Sioux Falls	1	0
Moody	42	11
Osan	2	1
Eglin	15	9
Total	170	49

[a] NRTS means not repairable this station.

d. Data Loss Problems

Lockheed Corporation in Fort Worth, Texas, has noted major losses of F-16 maintenance data during passage of data from CAMS into D056 and into REMIS. Data were not flowing from CAMS at the base level. As presented in Table V-11, at the peak of the problem, ten bases were without data flow. The problem affected data from 29 bases, one of them three times, and four of them twice. In one case, data flow did not occur for 13 months. In addition, duplicate data were sometimes transmitted from CAMS to REMIS.

In addition to analyzing regular maintenance data, Lockheed Fort Worth conducted separate analyses of F-16 TCTO data flow from CAMS to REMIS, CAMS to TICARRS, and from CAMS and D056 to D057G. D057G received only 4.6 percent of the records, and REMIS, only 33.6 percent. TICARRS received 98.2 percent of the records. CAMS personnel said that much of the problem was due to disruption from the release of RECFU II and that the data eventually were transmitted to D056 and REMIS. However, Lockheed was still unable to retrieve the data in June 1993.

e. Experience With REMIS

(1) EIMSURS Data. According to the results of our test, REMIS seems to provide accurate current data on mission-capable rates and possessed hours. Data from the 4th Wing showed very close correspondence to TICARRS and REMIS data in this area.

(2) Product Performance Subsystem Data. Litton Computer Services, the REMIS development contractor, reports a reject rate of just under 5 percent for on-equipment aircraft maintenance data for the period October 31, 1992, through January 2, 1993. Reject rates have increased considerably since RECFU II (see Table V-12). Aircraft systems, arguably the most important data point, have reject rates in the range of 8 to 11 percent. Reject rates for communication electronics and support equipment are expected to improve significantly soon due to recent fixes. Litton has set a goal of reducing the overall reject rate in the Product Performance Subsystem (PPS) to 7 percent and the aircraft reject rate to 5 percent or less by November 1993.

As of late May 1993, 46 system-to-system input (SSI) interfaces were operating without problems. However, one, CAMS on-equipment maintenance, was not operating at all, so that none of that data was reaching PPS. The fix for that problem was in system test. Three additional SSIs had processing logic problems, causing loss of data.

Table V-11. Missing Data Flow from CAMS to D056 and REMIS

Base	Stop Report Date	Fix Report Date	Months Missing
Andrews	2/22/93	3/17/93	0.83
Bergstrom	3/31/93	5/6/93	1.20
Carswell	4/14/93	5/20/93	1.20
Charleston	12/4/92	1/28/93	1.80
Des Moines	3/9/93	4/5/93	0.87
Edwards	3/3/93	4/5/93	1.07
Edwards	4/6/93	4/28/93	0.73
Eglin (Block 50 data)	2/19/93	3/8/93	0.63
Eglin	3/16/93	4/14/93	0.93
Eielson	2/22/93	3/17/93	0.83
Ellington	1/11/93	3/17/93	2.20
Fort Smith	2/22/93	3/17/93	0.83
Great Falls	4/26/93	5/20/93	0.80
Hancock	12/4/92	1/28/93	1.80
Hill	1/11/93	4/5/93	2.80
Hill	4/6/93	4/28/93	0.73
Hill	5/12/93	6/12/93	1.00
Hulman	1/11/93	6/7/93	4.87
Kelly	1/11/93	3/17/93	2.20
Kirtland	4/26/93	6/7/93	1.37
Luke	1/19/93	3/8/93	1.63
Luke	4/6/93	4/28/93	0.73
McConnell	11/18/92	3/8/93	3.67
Mountain Home	3/9/93	4/5/93	0.87
New Orleans	1/11/93	2/19/93	1.27
New Orleans	3/9/93	4/5/93	0.87
Niagara Falls	12/11/92	1/28/93	1.57
Peoria	3/9/93	4/5/93	0.87
Puerto Rico	12/1/92	6/11/93	6.33
Richmond	12/4/92	1/28/93	1.80
Springfield	2/15/92	3/18/93	13.10
Tinker	2/2/93	3/8/93	1.20
Truax	3/9/93	4/5/93	0.87
Tucson	1/11/93	3/8/93	1.90
Wright-Patterson	2/16/93	3/17/93	1.03

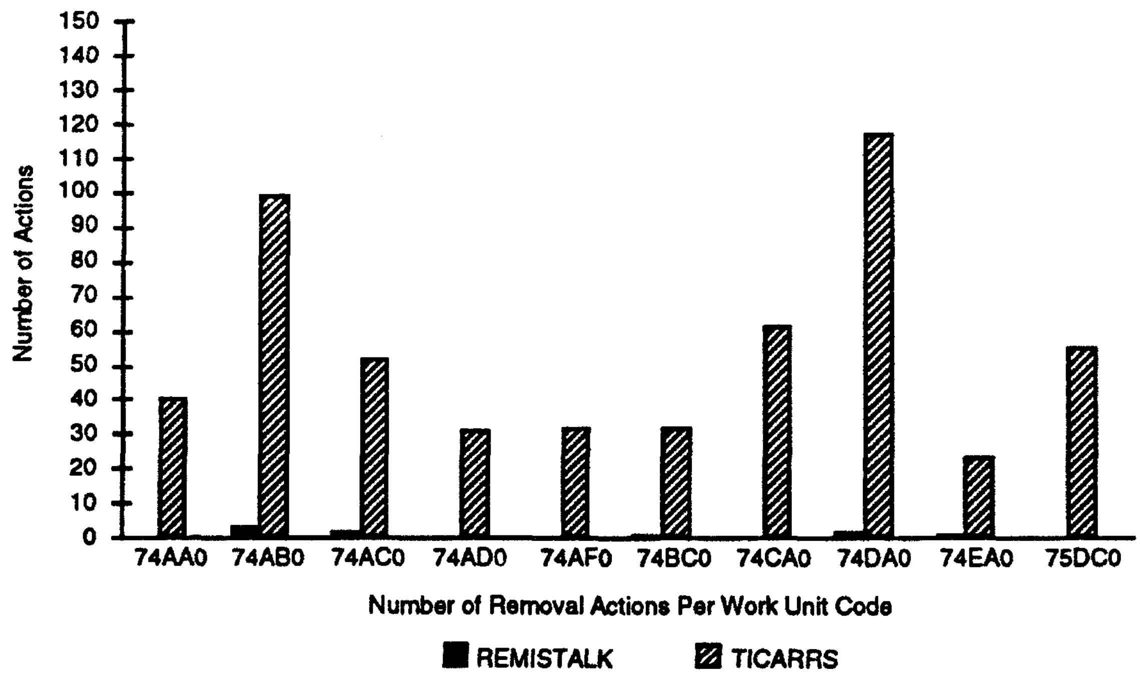
Source: Lockheed Corporation

Table V-12. Reject Rates in PPS for Selected Periods in 1993

Type of Equipment	February 22–March 15	March 17–April 15	April 16–April 28
Aircraft	10.7%	10.5%	8.5%
Communications-electronics	36.9%	47.9%	58.9%
Engines	14.7%	25.2%	39.7%
Support equipment	42.0%	74.2%	73.8%
Precision measurement equipment	59.4%	NA	NA
Missiles	5.6%	7.0%	45.5%
Trainers	87.5%	97.7%	93.5%
Total	20.7%	18.7%	15.7%

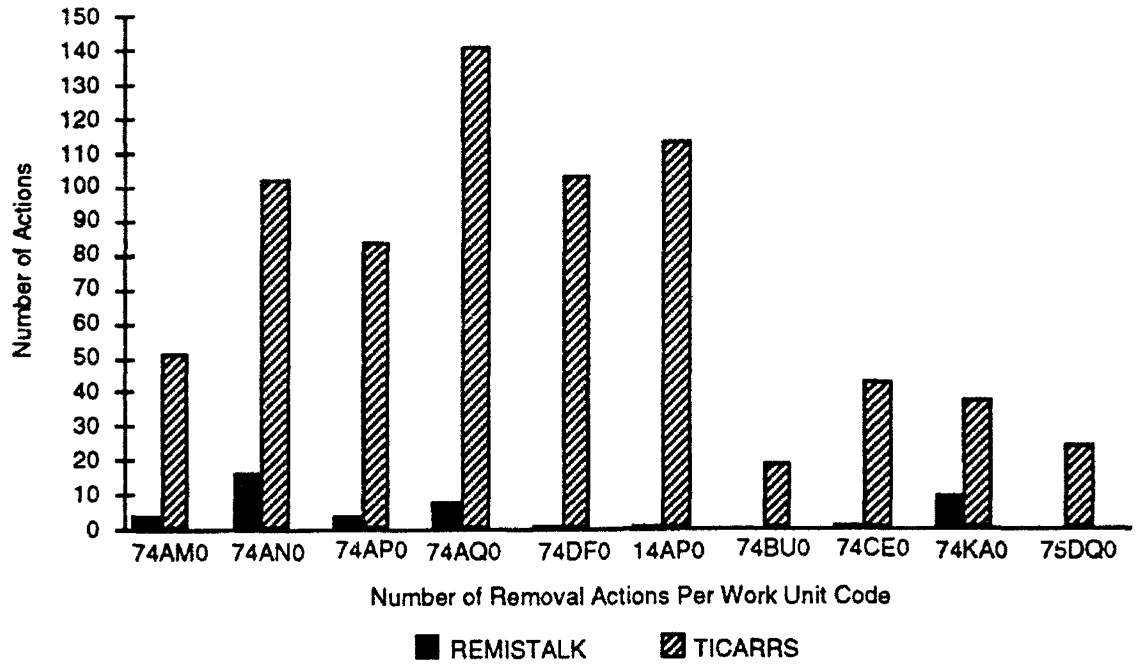
Note: NA means data were not available.

(3) LRU Removals Data. In April 1993, Lockheed Corporation compared LRU removals using TICARRS, REMIS standard query, and REMISTALK for a sample of 20 different WUCs, ten for the F-16A/B and ten for the F-16C/D. The REMIS queries were performed by the most experienced REMIS user at Ogden ALC. Results are presented in Figures V-8 and V-9.



Note: REMIS standard query found no data.

Figure V-8. Comparison of LRU Removal Actions by Work Unit Code for the F-16A/B



Note: REMIS standard query found no data.

Figure V-9. Comparison of LRU Removal Actions by Work Unit Code for F-16C/D

In every case, no data were found in the REMIS standard query. A small number of maintenance actions (never more than ten for any given work unit code) were found in REMISTALK. REMISTALK response times were in excess of 36 hours, well over the required standard of 24 hours. Only the TICARRS data seemed to provide a realistic number of removals for each WUC.

f. Test of REMIS Functionality and Selected Operating Characteristics

This section describes the results of an IDA test of REMIS functionality and status performed in late May 1993. IDA gave the CAMS/REMIS PMO and the F-15 SPO (TICARRS users) two identical data requests in late May 1993. The requests covered several aircraft types, and the data requested are typical of those we had seen requested by base, ALC, and MAJCOM users. The test focused on both: (1) the basic functions of REMIS and (2) specific areas of functionality that TICARRS users have requested be provided before TICARRS would be fully replaced by CAMS/REMIS.

Both REMIS and TICARRS were able to provide basic statistics—mission-capable rates and possessed hours—for the F-15E aircraft, 4th Fighter Wing, at Seymour Johnson AFB. Possessed hours agreed within 1 percent in the two data systems, while mission-

capable rates agreed within 0.1 percentage point. However, REMIS found no data for March and April of 1993. Complete results of the test are included in Appendix D.

REMIS did not provide additional Seymour Johnson data we asked for on MTBFs and MTBMAs.

We asked for data on mean time between maintenance actions (MTBMA) for F-15s, and both REMIS and TICARRS were able to provide reasonable data. The TICARRS data were only for U.S. aircraft, not F-15s worldwide, as requested.

We asked for all serial numbers within WUC 74 (fire control) that had more than three maintenance actions during the first quarter of 1993. TICARRS was able to provide this; REMIS provided an alternative report that listed the ten top man-hour-consuming systems for the F-15C by work unit code, not by serial number.

We also asked for data and maintenance narratives on the F-16 rotary flap actuator, a part that is tracked by TICARRS for warranty purposes. The only data provided by REMIS were maintenance actions and man-hours at the WUC level. TICARRS provided 68 complete narratives to illustrate its capability.

TICARRS users have complained that the algorithms in PPS, EIMSURS, and REMISTALK for calculation of mission-capable (MC) rates, mean time between repairs (MTBR), and mean time between critical failures (MTBCF) are not consistent with one another. The REMIS PMO's explanation was that different groups of users have different methods of calculating these variables. Developers have decided to wait for an Air Force policy on what the algorithms should be, and they will then be standardized across all modules.

We asked for several items from GCSAS in the second request. GCSAS was able to provide a list of current TCTOs for the B-1 (an aircraft not supported by TICARRS), but was not able to provide a list of approved and actual configuration for the same aircraft, because the actual configuration had not yet been loaded.

We asked for basic F-16C/D data. Both systems were able to provide most of the data we wanted. REMIS supplied only on-equipment not total, man-hours. TICARRS supplied two estimates of sorties, one based on debrief records that was similar to the REMIS number, and a second higher number based on utilization reports, that users say is more accurate. There were some major differences in the numbers.

In summary, in several cases, the REMIS data provided were for a different time period than requested, which prevented us from comparing the REMIS data with the

TICARRS data. In one instance, TICARRS provided data for U.S. F-15s only rather than worldwide F-15s, so we could not compare the data directly. REMIS provided some C-141 data not relevant to our request. (REMIS output on the C-141 is obtained through an interface with G081; the C-141 fleet does not use CAMS.)

With regard to ease of use, the difficulty of pulling data from the three subsystems of REMIS was obvious. Developers of the different subsystems of REMIS within LCS had to confer to determine which subsystem was the best one to use.

Furthermore, the people who retrieved the data for our test were experts. An average user would probably encounter even more difficulty. Aggregation—the ability to get a single bottom-line total without all the components—is difficult in the canned queries in EIMSURS and PPS. In many cases, REMISTALK, the customized inquiry utility, was the only way to retrieve aggregate data without a lot of extraneous output, and REMISTALK response times are considerably longer than those for standard queries.

The TICARRS data was retrieved by DRC representatives more easily and promptly than the REMIS data could be retrieved by REMIS developers. The TICARRS data were provided on letter-sized laser-printed paper and included a roadmap through the data. The REMIS response was on wide-carriage paper and was very difficult to follow.

2. TICARRS

TICARRS's central data base design provides the advantage that most of the data need to be handled only once, the initial entry into the TICARRS system. There is no question of inconsistent edits, as there is with CAMS and REMIS. Under TICARRS direct entry, errors are allowed to persist only long enough to allow flight line maintainers to do their work. All errors have to be corrected or addressed through supervisor review before a job can be closed out.

Lockheed Corporation has performed periodic physical inventories of serially-controlled components on F-16s during phase inspections at the 388th Fighter Wing and compared them with the data in the maintenance data systems. These data have been collected from June 1985 to the present and provide an indication of data accuracy for both direct entry TICARRS and CAMS. Figure V-10 shows the results in terms of the percentage of changes from one periodic inventory to the next that were not recorded in the data system. Under direct-entry TICARRS, incorrect data decreased steadily over time to an error rate of about 6 percent. With CAMS, missing data rates were considerably higher,

with the latest rate being 25 percent. It is not clear from existing data whether the trend is showing a decline or remaining stable within the 20- to 40-percent range.

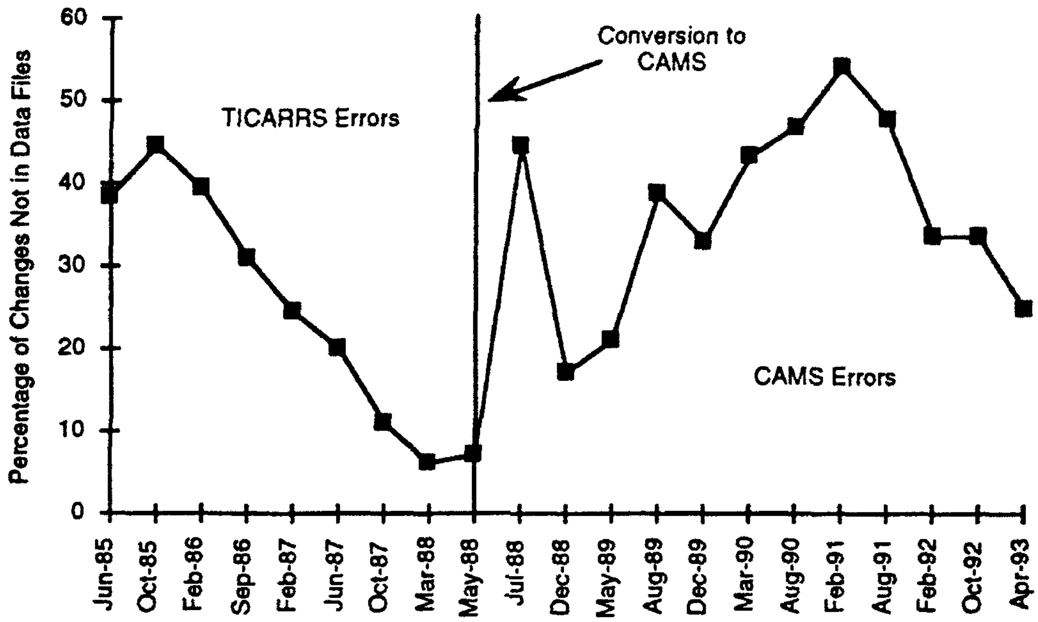


Figure V-10. Actual Inventories Versus Data Files

The Operational Assessment at Seymour Johnson AFB identified a number of instances where apparent software deficiencies in TICARRS led to problems of data accuracy and validity. Of the 149 Difficulty Reports (DIREPs) generated during the Operational Assessment, about 30 percent (approximately 47) led to data inaccuracies. Many of these were corrected during and immediately after the Operational Assessment with minimal resources.

3. Integrity and Security of Data Input

Another aspect of data accuracy and completeness is integrity and security. A maintenance data system requires procedures to ensure that only authorized persons can enter or change data.

If security procedures are inadequate, unauthorized persons can enter inaccurate data or change data. As noted previously, CAMS developers have acted to tighten security in response to an Air Force Audit Agency report. The current REMIS security procedures raise issues with configuration management.

REMIS requires a password before configuration data can be entered; however, once access is obtained, data can be entered on any system. REMIS developers are aware

of this difficulty, but have concluded that it is too difficult to resolve within the current REMIS architecture and cost constraints. TICARRS security allows segregation of configuration data entry by system.

4. Summary

The available information suggests that TICARRS under direct-entry provided better and more complete data than the current CAMS/REMIS system attains in most cases. A summary of our assessment of the capability of the systems to provide adequate data is presented in Table V-13. This assessment is based on the functions and associated accuracy requirements noted in Table III-1 of this paper.

Table V-13. A Comparison of Data Accuracy and Completeness

Function	Accuracy Requirement	CAMS/REMIS Accuracy	TICARRS Direct-Entry Accuracy
Safety of Flight			
Engines	99%	99%	Not Capable
Egress	99%	Unknown	92% to 96%
Mission-critical equipment	95% to 98%	68% to 76%	92% to 96%
Predictive R&M analysis and warranty tracking	90% to 98%	68% to 76%	92% to 96%
Wartime readiness, flying-hour program, and weapon system possession management	95%	95%	95%
R&M analysis, maintenance activities including production scheduling, and configuration management	70% to 90%	68% to 76%	92% to 96%

CAMS/REMIS has shown that it can provide highly accurate data for engines, where accuracy is very important. It also does an adequate job in the area of EIMSURS data. Outside the engine arena, however, product performance data appears to be much less accurate in CAMS/REMIS than in TICARRS.

Several significant problems in CAMS/REMIS need to be to fixed before it can routinely provide reliable data. There has not been sufficient time since the fix to RECFU II to assess whether data accuracy has improved. After that, CAMS and REMIS developers will have to tackle a large backlog of reported problems. In addition, CAMS suffers from inadequate data editing and data error control. Substantial effort must be expended to improve and enhance the CAMS editing capability to permit erroneous data entry to be caught and corrected when it is being entered. Because REMIS has the only fleet-wide

view of maintenance data, this work must be done in conjunction with REMIS to obtain an effective, complete, and accurate data-entry system and data base. In particular, high-speed communication lines between CAMS at the RPCs and REMIS will be necessary to allow the CAMS editing to obtain a fleet-wide view of the configuration, work unit code, and part and serial number data.

Direct-entry TICARRS has had fewer problems with data accuracy, perhaps because it supports fewer systems and types of equipment. It is not possible to say that expansion of TICARRS would be problem-free. Indeed, the Seymour Johnson experience indicates that there would be some problems. Nevertheless, the architecture of TICARRS, which would remain essentially the same under expansion, seems to result in more complete data, fewer errors, and more reliable error-correction when data is entered directly rather than through CAMS.

E. ADAPTABILITY

This section provides an overview of the adaptability of CAMS/REMIS and TICARRS to the future operating environment and condition of the Air Force. A more detailed discussion is provided in Appendix E.

Evaluating adaptability of these systems requires:

- an estimate of what the Air Force of the future will be like, and
- an assessment of the capability of the current systems to move toward the desired future environment.

1. The Future Air Force

The nature of the future Air Force with respect to factors that affect the operation and effectiveness of maintenance information systems depends on evolution in two areas: the operational policies and practices of the Air Force and technology. Over the time period of interest (the next seven to ten years) policies and practices can be expected to change because of the changed nature of the global military environment and because of the pressure that tight budgets place on the Air Force to find new efficiencies. Technology can be expected to change in weapon system design, in equipment fault diagnosis and maintenance, and in the features and portability of information systems. Since change in the Air Force does not occur overnight, our expectations are heavily weighted by current Department of Defense and Air Force initiatives.

Some key features of the expected future environment are as follows:

- rapid deployment of ad hoc force elements;
- greater use of two-level maintenance, placing a premium on data completeness and accuracy for identification of problem parts and on management of the repair and transportation process;
- relatively sparse operations and maintenance budgets that will require smart use of accurate data to maintain readiness;
- extensive built-in testing and status-reporting capability in new weapon systems;
- use of automated maintenance aids that incorporate aspects of artificial intelligence will use maintenance data to aid in fault diagnoses; and
- user-friendly information systems that minimize the need for data entry.

In light of these expected developments, the weapons maintenance information system of the future must be capable of providing the following strategically important features:

- be deployable at the squadron level,
- be adaptable to new weapon systems, maintenance technology, tools and procedures,
- be able to interface with other systems,
- be able to adapt to Air Force organizational changes and processes,
- provide accurate and timely data,
- take advantage of emerging information system technology to provide user-friendly (user productive and efficient) data collection and data access,
- permit access to centralized data for a fleet-wide perspective of status, reliability, and maintainability data, and
- not be too expensive.

We envision a maintenance information system that is oriented around squadron-level modules that use local area networks (LANs) and client-server data base systems (CSDSs). The squadron-level data base has access to and may be accessed both by the wing CSDS and by a central data repository for all Air Force weapon systems. Deployed squadrons also use the CSDS-LAN system configuration, but are able to sustain operation without continuous communication to the central repository. The deployed squadron periodically uses satellite links to communicate essential data to and from the central repository.

At the squadron level, LANs are used to communicate with a variety of work stations and test stations, all of which use a standard LAN adapter and common serial/parallel interface. Test equipment, smart terminals, or workstations, which are linked to hand-held and integrated data collection devices (IMIS or F-22 AIMS), are interfaced with the LAN to send data to the CSDS. This interface is facilitated by using standard interfaces and common communication protocols. Modern software programs that use Windows-type techniques allow personnel entering data to select from lists rather than to enter the data manually, and smart personal computer terminals provide graphics displays and voice response units to allow critical data to be analyzed and to help in training new personnel.

2. Capability of Current Systems to Move Toward the Future Environment

The foregoing vision of how the Air Force's maintenance information system needs to evolve was developed by IDA. It was based on information received from the CAMS/REMIS Program Office, Dynamics Research Corporation, the F-22 System Program Office, and other government and industry sources. The technological path is not difficult to visualize; however, the right way to adapt to it in the Air Force environment is not so easy to envision. It is unlikely that the kind of information system the Air Force needs can be designed and put in place simply. Current systems and procedures must be dealt with, and such systems are not replaced quickly. Selection of technologies and products, hardware and software, must be such that they can be evolved into an information system that takes full advantage of the emerging technologies to meet the needs of the Air Force.

The existing weapons information systems, CAMS/REMIS and TICARRS, are the starting points for the information system technological path. Does one of them stand out from the other as the obvious choice to serve as the foundation for evolving to the system of the future?

a. CAMS/REMIS

CAMS would no longer be necessary in the type of system described above. Once the squadron CSDSs were established, base by base, and interfaced directly with REMIS, CAMS would simply be replaced, functionally and physically. CAMS does not have the function or structure to perform well in a client-server environment. CAMS hardware and software are not built to allow users to operate it independently of the mainframe system. The architecture is not well-suited to support the movement away from mainframes to high-

speed, high-capability networks of computers and communications equipment. In addition, the wing-oriented nature of CAMS makes the development of data bases tailored for rapidly assembled deploying squadrons very difficult.

REMIS has several architectural features that will be required by a central repository. First, it has a data base that is designed to contain fleet-wide data. Second, it has a very good (but inefficient) network management program, and it has the mechanisms needed to download data and programs to CSDSs. It also has a capability to interface with other systems. However, the REMIS implementation of its data report mechanism may be a continuing problem. A key concern is that the REMIS data base structure (relational) may not be well-suited to provide expeditious central data reporting capability. REMIS is having trouble with this issue now. It may be intrinsic to the system architecture.

b. TICARRS

The TICARRS system architecture allows relatively rapid addition of new weapon systems and equipment. It also has a mechanism for bulk input/output, which could be the basis for interfaces with other systems (as it is now with CAMS). TICARRS currently supports a LAN system for the Maintenance Operations Center (MOC), which could be the foundation for more sophisticated support. The TICARRS Conversation Manager software would not be required to support a squadron CSDS. TICARRS uses a network type data base, which is suited to handling many data base activities rapidly. While TICARRS performance was satisfactory when supporting the F-16 fleet with direct input, it remains to be seen how it would measure up in a full fleet-wide support environment.

Neither REMIS nor TICARRS has a distinct technical advantage relative to each other in terms of its ability to serve as the basis for the future system. TICARRS has demonstrated a capability to rapidly and efficiently change its application software to meet new requirements; however, in terms of the next-generation maintenance information system requirements, it possesses a slight technical advantage over REMIS (due to REMIS's lower processing speed), but clearly not sufficient to weigh heavily in its favor. While parts of each system might be useful in future development efforts, we believe that both are likely to be overtaken by emerging technologies and trends in information processing.

F. LOGISTICS AND OPERATIONAL EFFECTIVENESS

1. Objective

This section of the report describes the effect (or lack of effect) of CAMS/REMIS and TICARRS on maintenance-related support and weapon system performance. The objective was to determine if it can be demonstrated that the information systems significantly affect the logistics support and operational environment. The analysis focuses on short-term effects from changes to information system support of the weapon systems.

A comparison is made of support and performance over the period of time when TICARRS users were required to switch from direct entry into TICARRS to entry through CAMS and then into TICARRS. Weapon systems supported by TICARRS are the focus here, but two non-TICARRS weapon systems are included to control for any simultaneous changes in Air Force activities that might obscure the true effects of the information systems.

2. Approach

The approach was to use a time series of weapon system and logistics performance data for tactical weapon systems to create a historical snapshot from which the conversion from direct-entry TICARRS reporting to CAMS-entry TICARRS reporting can be evaluated. The CAMS conversion dates were then "overlaid" onto these trends to determine if there were significant differences in pre- and post-CAMS conversion performance. Formal statistical tests were used to evaluate these time trends.

Data requests were made of DRC and the CAMS/REMIS Program Management Office (PMO) to provide the following information:

- inventory, status, and utilization data for tactical weapon systems over the period 1982 through 1992 and
- product performance data, including failures, demands, and maintenance man-hours, by two-digit work unit code for the same weapon systems.

DRC provided these data for all F-16 and F-15 weapon systems on the TICARRS system. The CAMS/REMIS PMO was unable to provide all of the information requested, and limited its response to providing weapon system performance data only, for F-111s, F-4Es, and other weapon systems for the recent past. A similar request to ACC yielded more historical data for non-TICARRS weapon systems.

Weapon system performance was measured by the mission-capable (MC) rate. The MC rate is the fraction of possessed hours that aircraft are either fully mission capable or partially mission capable. The hypothesis tested was that wings had higher MC rates with one of the information systems than with the other. This would reflect well on the information system associated with higher aircraft availability.

If a better information system enhances aircraft availability, this is presumably the result of either parts breaking less (perhaps because problem parts are eliminated from the system) or being fixed more quickly (or both). Mean time between failures (MTBF) and maintenance man-hours per flying hour (MMH/FH) were examined as a function of the information system in use. The analyses concentrated on fire-control, which includes radar and inertial navigation system equipment (WUC 74).

The hypotheses that the information system being used could be linked to MC rates, MTBF, and MMH/FH were tested in two ways. The first focused solely on the F-16 weapon system and its conversion from direct-entry TICARRS to CAMS-TICARRS, entry which occurred during the period from late 1988 through 1989. Time trends not associated with the conversion from TICARRS to CAMS were corrected.

The second test focused on three weapon systems—F-16, F-111, and F-4E—all of which had increasing or level MC rates over the relevant period of this evaluation. The analysis examined how the MC rate changed from the period before CAMS conversion for the F-16 began to the period after it was completed. If CAMS helped, one would have expected the F-16 to have improved significantly more between the two periods. A finding that the F-16 improved less would have indicated that TICARRS supported wing operations and maintenance better than CAMS.

A detailed discussion of the results of our statistical analyses is provided in Appendix F. The results are summarized below.

3. Results

The analyses consistently indicated that the conversion to CAMS-entry from direct-entry TICARRS for the F-16 weapon system produced no significant change in weapon system performance. Compared with the F-111 and F-4E, the F-16 exhibited no differences in MC rates during the period of conversion to CAMS entry. Regarding product performance of a selected WUC for the F-16 aircraft, the results indicate that the conversion itself did not affect MTBF or MMH/FH, although some time-sensitive variations occurred during the conversion period.

These results do not necessarily mean that the choice of system is not important to logistics performance or aircraft readiness. The analysis presented above is, by design, limited to short-term impacts of the information systems on logistics and weapon system performance measures. Impacts that are visible only over a longer time period must not be ignored. An important reason for wanting maintenance data is to facilitate identification of problem parts and potentially worthwhile modifications. The value of data in these roles would only be evident over a longer period of time, and would be unlikely to be identified in the analyses discussed above. Just as important, the fact that operational effectiveness under the two systems is essentially equal does not necessarily mean that the systems make no difference. Wing personnel may find technical work-arounds to overcome problems with the information systems, or the Air Force may maintain readiness by using more resources (like buying more spares or working longer hours). Unfortunately, these kinds of adaptations are difficult to detect. The analysis presented here should not be taken to mean that better data have no payoff to the Air Force.

G. SUMMARY

This chapter has provided a great deal of detail about the effectiveness of CAMS/REMIS and TICARRS. It lays the foundation for our definition and estimation of viable alternatives to the current maintenance data support environment. Chapter VI presents the alternatives and Chapter VII provides the cost calculations for those alternatives.

A summary of the capabilities and deficiencies of CAMS/REMIS and TICARRS is presented in Table V-14.

Table V-14. Summary of Effectiveness Analysis

Dimension of Effectiveness	Conclusion
Functionality	Greater for CAMS/REMIS
Scope	Greater for CAMS/REMIS
Operating characteristics	
Availability	Better for TICARRS
Responsiveness	Better for TICARRS
Ease of use	Equal at wing level, TICARRS better elsewhere
Data accuracy and completeness	Better for TICARRS
Adaptability	TICARRS better in short-term; little long-term difference
Logistics and operational effectiveness	No difference found

The most important differences in system effectiveness are that CAMS/REMIS has greater functionality and much greater scope than TICARRS, but TICARRS has better operating characteristics and, more important, has demonstrated a greater ability to develop and maintain accurate data.

VI. DEFINITION OF ALTERNATIVES

This report has provided evidence that both CAMS/REMIS and TICARRS have limitations that should not be present in an Air Force standard maintenance system. This chapter outlines enhancements that should be made and areas that must be addressed in each system. The enhancements are presented in the context of two alternative scenarios regarding the future of these systems:

- Alternative 1: an enhanced version of CAMS/REMIS that incorporates improvements that are either under way or planned for the near future. With this alternative, CAMS/REMIS, with needed enhancements, continues as the Air Force's standard system. TICARRS is retired, though it continues to operate until REMIS reaches full operational capability.
- Alternative 2: an enhanced version of TICARRS 92 that is expanded in function and scope to allow it to perform all the tasks it must perform to replace CAMS/REMIS. TICARRS becomes the Air Force standard system. CAMS/REMIS is retired. Because of the length of time it will take to complete all the functional and administrative steps necessary to make TICARRS the Air Force standard maintenance information system, the development of REMIS will proceed to full operational capability. The Generic Configuration Status Accounting System (GCSAS) will be deployed, and the information systems that REMIS is designed to supplant (except for TICARRS) will be turned off. Some investment will be made to improve the performance of REMIS, and the costs involved in developing accurate configuration information for GCSAS will be incurred. CAMS efforts pertaining to Computer System Requirements Document (CSRDs) will continue. Other development efforts related to CAMS will cease.

Each of these alternatives is explored in the subsections that follow.

Regardless of which alternative is pursued, we assume that the system not chosen will continue to operate until the system that is chosen reaches full operating capability. At that point, the systems would exhibit roughly equivalent functionality, scope, operating characteristics, and so on. Chapter VII contains estimates of the costs to implement these enhancements and includes costs of the transition to a single system.

A. ALTERNATIVE 1: ENHANCED VERSION OF CAMS/REMIS

1. Areas of Enhancement for CAMS

As was discussed in Chapter V, CAMS suffers from poor availability and poor transaction response time. Unfortunately, it is unclear how much of the problem is tied to CAMS software and how much is due to inadequate base-level operations. The evidence indicates that CAMS has good performance and good availability at a few bases, leading to the conclusion that the base-level operation must be a major contributor to the problem. The move to Regional Processing Centers (RPCs) is expected to improve the situation. Even so, CAMS software reliability must be examined on a continuing basis to ensure that it is not contributing to availability problems. This must be an ongoing effort of the CAMS maintenance staff.

With any large data system, there is a continual need for human and dollar resources to correct problems and defects and improve system performance. CAMS is no different, but it suffers from a long backlog of reported but unresolved problems. In the past, priority has been placed on developing the increments of new capability rather than on correcting problems or improving system performance.

An effort is being made by the current CAMS management to address some of these problems. A special $1 million optimization effort is ongoing with contract assistance from the Harris Corporation. This effort is limited to useability problems (e.g., use of multiple screens, improved error messages, etc.). In addition, there is currently a 30-staff-year backlog of approved functional modifications (CSRDs) to CAMS. In the cost analysis described in Chapter VII, we included personnel to address these kinds of software maintenance problems.

CAMS also suffers from inadequate data editing and control. Substantial effort must be expended to improve and enhance CAMS's editing capability to permit erroneous data entry to be identified and corrected when data are entered. Because REMIS has the only fleet-wide view of maintenance data, this work must be done in conjunction with REMIS to obtain an effective, complete, and accurate data-entry system and data base. In particular, high-speed communication lines between CAMS at the RPCs and REMIS will be necessary to allow the CAMS editing to obtain a fleet-wide view of the configuration, work unit code, part number, and serial number data. The editing enhancement would totally replace the current process of REMIS responding to the individual bases with error

messages an hour or two after the fact, with the expectation of error correction by the flight-line personnel or the CAMS data base manager.

2. Areas of Enhancement for REMIS

Several key REMIS performance issues must be addressed. Although response time is adequate for simple transactions, it is very slow for users requesting reports, especially ad hoc reports. The following areas should be addressed to speed up the REMIS report-generation:

- Balance the central computer workload. As discussed in Chapter V, most of the load is currently on HQ1.
- Reduce the amount of computer resources used. The programs that make up the network control system (operations overhead) and those that process input from CAMS (system-to-system input) will need to be redesigned and recoded.
- Add computing power. Additional computing power will be necessary to handle the full workload expected by REMIS.
- Reduce the time required to access data through REMISTALK.

3. Transition Schedule

TICARRS would be phased out beginning when REMIS reaches full operational capability (projected for January 1995). Since the weapon systems supported by TICARRS are also supported by REMIS, we assume that the phasing out could be done quickly. For the purposes of the analysis, we assumed this would be done over a three-month period (January through March 1995). Thus, TICARRS would operate throughout FY 1994 and through the first six months of FY 1995. The process of developing improvements to CAMS and REMIS would continue until the end of FY 1996, and operational test and evaluation would occur in FY 1997.

B. ALTERNATIVE 2: ENHANCED VERSION OF TICARRS

1. Areas of Enhancement for TICARRS

If TICARRS is to become the standard Air Force maintenance system, it must be expanded to cover all weapon systems currently covered by CAMS/REMIS. TICARRS would have to be activated to support 89 Air Force bases. The following major steps must be taken to accomplish this:

- Additional hardware must be purchased in order to handle the greatly increased demands on processing and data storage.

- The application software must be enhanced. Eight enhancements have been identified as necessary to give TICARRS the required functionality. They are:
  - Comprehensive Engine Management System (CEMS) interface,
  - Standard Base Supply System (SBSS) interface,
  - aerospace ground equipment,
  - production scheduling (comparable to CAMS 380 screen),
  - maintenance snapshot (comparable to CAMS 122 screen),
  - automated aircraft forms,
  - personnel and training, and
  - Product Quality Deficiency Report (PQDR).
- The data base must be initialized for each of 44 weapon systems, simulators and trainers, tactical missiles, and communications-electronics equipment.
- Communications must be added from the bases to TICARRS to allow direct input.
- A total of 254 units must be activated and users trained. This estimate takes the expected reduction in the size of the Air Force into account.

Estimates of the resources required for each of these steps are discussed in Chapter VII.

2. Transition Schedule

We assumed that, before TICARRS can become the standard Air Force maintenance data system, it must proceed through a complex acquisition review process. Five major activities must be completed before TICARRS could be considered fully deployed:

- contract award,
- system development,
- operational test and evaluation,
- Major Automated Information System Review Council (MAISRC) review, and
- deployment.

Figure VI-1 shows the development, approval, and deployment schedule that has been used in developing the costs that are presented in Chapter VII.

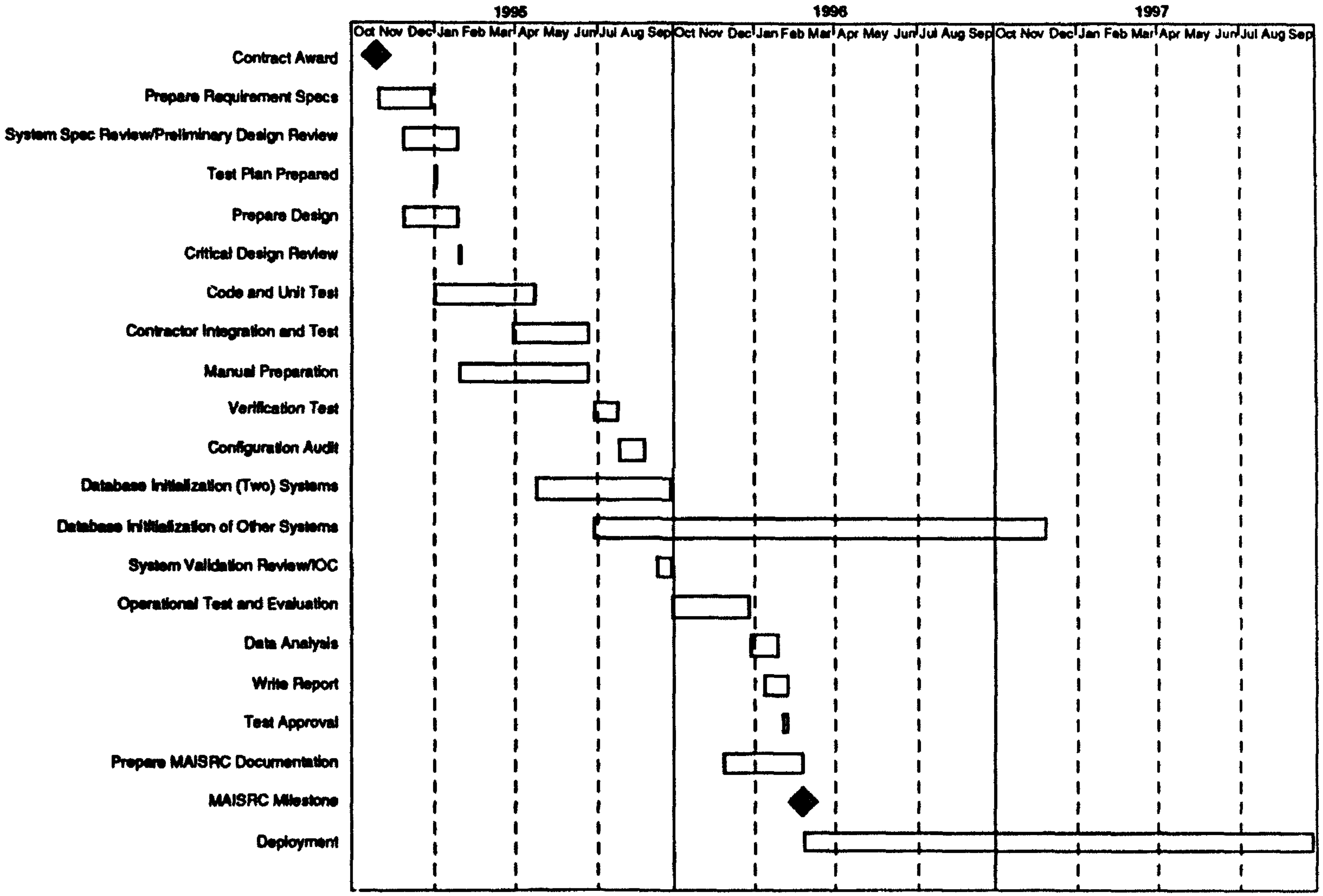


Figure VI-1. Projected Schedule for Development, Review, and Deployment of TICARRS

Despite the fact that DRC developed TICARRS and has been operating and maintaining it for years, Department of Defense regulations specify that a formal selection process must be completed before TICARRS can be enhanced. This could be done through either a sole-source justification or a competitive procurement. The Air Force believes that this process is likely to take about a year. If a decision is made in October 1993 to go with Alternative 2, the contract could be awarded around 1 November 1994. After that, the other scheduled activities could proceed to full operational capability.

Modifications to the system must be designed, and the design must be approved. Coding can begin before design is complete. The software must be tested. Documentation can be prepared during the coding and contractor testing period.

A data base structure must be developed for the aircraft (or other systems) to be used in the operational test and evaluation (OT&E). The OT&E itself is expected to take four months, followed by two months of analysis and report preparation. System development and preparation for MAISRC review could be expected to take 16 months from the date of contract award. This would lead to MAISRC approval in March 1996. At that time, deployment of TICARRS to operating bases would begin.

We estimate that deployment to the 254 units expected to be in service at the time could be completed in 19 months. As locations are converted to TICARRS, CAMS would be shut off. REMIS would be terminated when the deployment is complete, at the start of FY 1998.

Delays in the acquisition process, such as might be caused by contracting protests or slippage in the development and approval process, could push the completion of deployment deep into FY 1998. Chapter VII includes sensitivity analysis to account for these potential delays. On the other hand, progress in the ongoing efforts to simplify the acquisition process could speed things up. The cost implications of delays to the process are investigated as an excursion in Chapter VII.

C. RISK ASSESSMENT

The two alternatives contain a number of important changes to the existing Air Force maintenance information systems. As with any developmental effort, there is risk. In this assessment, the risk involves the systems not being able to perform as well as desired after spending the specified amount of money on development.

Table VI-1 assesses the riskiness of the two alternatives with respect to the most critical elements of effectiveness discussed in Chapter V and estimated in Chapter VII.

Table VI-1. Assessment of Technical Risk Associated With Alternatives

Aspect of Effectiveness	Alternative 1	Alternative 2
Functionality	None	Low
Scope	None	Low
Operating Characteristics	Low-Medium	Low
Availability	Medium	Low
Response Time	Medium	Low
Ease of Use	Low	Low
Data Accuracy and Completeness	Medium	Low

Overall risk is low to medium for Alternative 1 and low for Alternative 2.

The move to Regional Processing Centers will not, by itself, improve the availability of CAMS. Improvements to availability are dependent upon: (1) improved software quality and (2) the provision of the appropriate mix of skilled personnel (data base managers) at the bases.

Regarding CAMS/REMIS response time, it should be possible to adequately improve the responsiveness of REMIS, but there is more risk involved because of the architecture of the system.

The biggest potential problem involves the completeness and accuracy of CAMS and REMIS data. The completion of GCSAS might improve the situation, but the complex nature of the interface between the two systems, and the data rejects that may still result, could result in data that are not accurate enough to meet some of the Air Force's requirements (as described in Table V-13).

Even though deficiencies of scope and functionality are major weaknesses of TICARRS today, the flexibility of the system's architecture supports optimism about TICARRS's ability to be expanded as needed.

VII. ESTIMATING THE COSTS OF ALTERNATIVES

This chapter contains the cost analysis for the alternatives defined in Chapter VI. To facilitate comparison, the analyses follow a common cost element structure.

A. INTRODUCTION

First, we explain our assumptions concerning cost, then we present the costs of the individual information systems. Section C presents the cost analysis for CAMS, Section D, for REMIS; and Section E for TICARRS. Section F discusses cost drivers, and Section G presents the costs of the two alternative approaches to meeting the Air Force's needs for maintenance information that were developed in Chapter VI. Both of the alternatives include cost components associated with all three individual systems. Alternative 1 includes 18 months of TICARRS costs because REMIS is not expected to be fully functional until late 1994. Alternative 2 includes four years of CAMS/REMIS costs because we expect enhancement and expansion of TICARRS to take that long if we assume it undergoes a Major Automated Information System Review Council (MAISRC) review.

CAMS, REMIS, and TICARRS vary in terms of the detail and visibility of associated costs. By far the greatest amount of detail was available for REMIS. In preparation for the MAISRC Milestone III, a Program Office Estimate (POE) and an Independent Cost Estimate (ICE) were prepared. Detailed cost projections were also available from Litton Computer Services (LCS).

CAMS costs proved to be difficult to obtain because they are spread across many different organizational boundaries. As previously stated, the Standard Base Level Computer (SBLC) and the Regional Processing Center (RPC) costs are fundamental cost drivers of the CAMS costs. Since the operation of the SBLCs are funded through the Major Commands (MAJCOMs), there does not appear to be a single source to obtain individual base-level SBLC costs, or the SBLC costs attributable to CAMS. Much of the CAMS operations and maintenance (O&M) costs were based on the Air Force Business Case Analysis supporting the DMRD 924 initiative and data provided by the DMRD 924 Program Management Office (PMO) at Gunter Standard Systems Center (SSC).

TICARRS had adequate documentation of current and historical costs. The major issues for this system concern the costs to expand the functionality of TICARRS and to transition 254 units at 89 bases from CAMS to TICARRS.

B. ASSUMPTIONS

This section outlines the general assumptions we made concerning the systems being estimated. For all the cost estimates, we used FY 1994 constant dollars.

1. Contractor Labor

We assumed 1,920 hours per staff-year for contractor labor. The hourly rate assumed for software and data base design and implementation is $60 per hour burdened plus an additional 15 percent for general and administration (G&A) expenses plus fee for a total hourly rate of $69. Multiplying by 1,920 hours per year gives an annual rate of $132,480. The burdened hourly rate assumed for computer operators is $35 plus an additional 15 percent for G&A plus fee for a total hourly rate of $40.25 (or $77,280 per year). Those rates apply to all contractor labor costs, unless otherwise noted.

2. Air Force Military and Civilian Personnel

Air Force Regulation (AFR) 173-13, Attachment 32, Table A32-1, lists the pay for the military grades, and Attachment 31, Table 31-1, lists the civilian paygrades. Unless otherwise noted, the paygrades used were GS-09 at $49,885 for civilian and E-6 at $48,622 for military employees. The amounts indicated are the Accelerated Annual Pay Rate for FY 1993 based on the FY 1994 President's Budget and adjusted to FY 1994 dollars. Accelerated annual pay for military personnel includes the costs of government-furnished quarters for personnel living in family housing or dormitories and not receiving Basic Allowance for Quarters (BAQ) payments; the costs of preparing and serving food in the dining room; medical costs covered by the O&M appropriation; and commissary and exchange benefits subsidized by appropriated funds. Accelerated annual pay for Air Force civilian personnel includes funded and unfunded retirement and benefits. The Air Force civilian factor follows the Office of Management and Budget (OMB) A-76 guidelines.

Contractor costs include certain overhead costs (e.g., facilities) that are not included in the DoD military and civilian rates listed above. For cost comparison purposes, the DoD

rates were increased by the amounts listed as non-pay cost factors in AFR 173, Attachment 56, Table A56-1. Those factors are as follows:

- Air Combat Command (ACC)—$6,100 per year,
- U.S. Air Forces Europe (USAFE)—$14,600 per year, and
- Pacific Air Force (PACAF)—$9,600 per year.

The installation support costs must be added to make costs for Air Force personnel comparable to costs for contractor personnel. The cost factors include base operations, base communications, real property services, maintenance and repair, child care, and other base overhead costs. This will result in some variations in the cost of personnel between MAJCOMs. In addition, much of the cost data provided did not include a break out of civilian and military personnel. Where such information was provided, it was used; otherwise, the personnel costs are based on an average of the selected civilian and military paygrades. The actual values used in the calculations may vary depending upon the weighted mix of military and civilian personnel.

3. Miscellaneous Assumptions

There are a number of other assumptions, including:

- cost estimates cover a ten-year period from FY 1994 through FY 2003,
- there are 89 bases and 254 units (information provided by the Air Force), and
- hardware will be replaced/upgraded after seven years. Replacement cost will be based on the same number of units but reduced in price (20 percent per year) as a result of advances in technology.

It should be noted that these estimates do not represent programmatic costs and are not intended to serve as the basis for congressional appropriations. The estimates for CAMS, for example, cut across several program boundaries. Our objective was to estimate all relevant costs associated with each system, regardless of the particular organization responsible for those costs.

The following sections discuss the derivation of the cost estimates. In the cost tables, we have rounded to two significant digits. In some cases, the numbers may not add due to rounding error.

C. COST ESTIMATE FOR CAMS

The CAMS cost estimate presented here includes both the recurring and nonrecurring costs to the Air Force of operating CAMS. Some of these costs are not included in the CAMS budget, but rather are incurred by other organizations in the Air Force and are not tracked as CAMS expenses. An example of this is the cost of operating the RPCs and SBLCs at each base. A significant portion of the SBLC and RPC cost is due to CAMS operation, but there are no accounting data to substantiate what that portion is. Similarly, the cost of military personnel is not reflected in some of the budgets. The study team cost projections include estimates of the funds required for these type of expenditures.

The CAMS costs for the years FY 1994-2003 are heavily influenced by the SBLC regionalization initiative (DMRD 924). All of the computer support for the SBLC bases in the continental United States (CONUS) and the Air National Guard (ANG) and Air Force Reserve (AFRES) bases are planned to have completed or started the move to RPCs by end of calendar year 1994. Only 14 out of a total of 76 bases will remain to be completed by mid-year 1995. In addition, the SBLCs in USAFE and PACAF have plans to regionalize during 1994. The cost estimate for CAMS assumes that all 89 bases will be served by RPCs in 1994 and beyond.

The RPC cost projections provided by the RPC PMO were in two categories, (1) investment or nonrecurring costs in budget program (BP) 3080 and (2) operations and maintenance or recurring costs in BP 3400. This information was a subset of the information provided by the Air Force Business Case Analysis supporting DMRD 924 (dated 13 December 1991). In addition, discussions with the RPC PMO personnel resulted in information and system usage data that provided the basis for estimating the cost of the RPC operation due to CAMS.

The personnel costs for the RPC organizations are based on the identification of military and civilian employees provided by the CONUS RPC. This yielded an average cost of $55,870 after the application of the ACC non-pay cost amount mentioned previously. PACAF and USAFE costs were correspondingly higher.

Personnel costs were rated at an average of the civilian and military rates when the military and civilian employee numbers were not identified. The ACC amount was added to this average, resulting in a pay of $55,660.

Table VII-1 summarizes the costs estimated for CAMS by cost element. The individual cost elements are discussed in the subsections that follow. The numbers shown in parentheses correspond to the numbers to the left of the cost categories in the table.

Table VII-1. Cost Estimate for CAMS

	Category of Cost	Cost in Millions of 1994 Dollars										
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hardware											
1.1.1	CAMS share of RPC Hardware											
	CPUs	6.00							2.05			8.06
	Disks	0.39							1.55			1.95
	Silos	5.24							1.34			6.58
	Print Stations	1.80							0.38			2.18
	CAMS Share of USAFE Hardware	0.25							0.04			0.29
	CAMS Share PACAF Hardware	2.00							0.33			2.33
1.2	Software											
1.2.1	Application Software											
	Approved CRSD	1.32	1.32	1.32								3.97
	Enhanced Editing	1.98	1.98	1.98								5.95
	System Integration and Test	0.28	0.28	0.28								0.84
	OT&E Support				1.25							1.25
1.2.2	Data Base Initialization											
1.2.3	Documentation	0.33	0.33	0.33								0.99
1.3	Communications											
1.4	Training											
	Nonrecurring Subtotal	19.60	3.92	3.92	1.25	0.00	0.00	0.00	5.70	0.00	0.00	34.38
2.0	Recurring Costs											
2.1	Program Management											
2.1.1	Government	0.80	0.80	0.80	0.45	0.45	0.45	0.45	0.45	0.45	0.45	5.53
2.2	Computer Operations											
2.2.1	RPC CONUS Operations											
	Direct Personnel	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	5.59
	Shared Personnel	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	46.34
	Hardware, Software, and Utilities	2.88	2.45	2.22	2.29	2.29	2.29	2.29	2.29	2.29	2.29	23.60
2.2.2	RPC PACAF Operations											
	Direct	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.17
	Shared Personnel	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	6.55
	Hardware, Software, and Utilities	0.51	0.43	0.39	0.41	0.41	0.41	0.41	0.41	0.41	0.41	4.18

Table VII-1. Cost Estimate for CAMS (Continued)

	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
		Cost in Millions of 1994 Dollars										
2.2.3	RPC USAFE Operations											
	Direct Personnel	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	1.27
	Shared Personnel	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	8.02
	Hardware, Software, and Utilities	0.58	0.49	0.44	0.46	0.46	0.46	0.46	0.46	0.46	0.46	4.72
2.2.4	Base Comm. Ops. CONUS											
	Civilian and Military Personnel	7.36	7.36	7.36	7.36	7.36	7.36	7.36	7.36	7.36	7.36	73.65
	Hardware, Software, and Utilities	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	21.62
2.2.5	Base Comm. Ops. USAFE											
	Civilian and Military Personnel	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	16.84
	Hardware, Software, and Utilities	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	4.59
2.2.6	Base Comm. Ops. PACAF											
	Civilian and Military Personnel	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	5.13
	Hardware, Software, and Utilities	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.53
2.3	User Support											
2.3.1	Field Help Group	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	6.12
2.3.2	Base Representatives	17.82	17.82	17.82	17.82	17.82	17.82	17.82	17.82	17.82	17.82	178.25
2.3.3	Data Base Maintenance	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.34
2.4	Communications											
2.4.1	RPC High-Speed Base Links	0.62	0.82	0.85	0.88	0.88	0.88	0.88	0.88	0.88	0.88	8.47
2.4.2	High-Speed REMIS Link	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	2.10
2.5	Software Maintenance											
2.5.1	Applications Software	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	25.05
2.5.2	System Integration and Test	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	5.01
2.5.3	Data Base Management	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	2.23
2.5.4	Documentation	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	2.78
2.6	Training and Travel	0.43	0.43	0.43	0.37	0.37	0.37	0.37	0.37	0.37	0.37	3.87
	Recurring Subtotal	47.65	47.25	46.96	46.67	46.67	46.67	46.67	46.67	46.67	46.67	468.55
	Total Costs	67.24	51.17	50.88	47.92	46.67	46.67	46.67	52.37	46.67	46.67	502.93

1. Nonrecurring Costs (1.0)

a. Hardware (1.1)

The CAMS share of the CONUS Regional Processing Centers hardware costs was established by determining the CAMS utilization of the major hardware units in the RPCs. Measurement data provided by the RPC PMO enabled the study team to develop CAMS average hardware utilization rates, which, in turn, were used as the basis for establishing the CAMS share of the hardware cost. Average CAMS utilization for the major hardware units are shown in Table VII-2.

Table VII-2. CAMS Share of RPC Hardware Costs (1.11)

Organization and Equipment	FY 1994 Cost (Millions)	Percentage CAMS
CONUS RPC Computers	$34.3	17.5%
CONUS RPC Disks	$3.2	11.9%
CONUS RPC Silos	$28.3	14.8%
CONUS Base Print Stations	$7.2	25.0%
USAFE RPC Upgrades	$1.6	15.6%
PACAF RPC Hardware	$12.5	16.0%

The CAMS utilization percentage was calculated by adding the CAMS share of transaction processing utilization, executive processing, batch processing, and demand processing as determined by the RPC data. The RPC computer equipment has been planned with an excess capacity of 25 percent to allow for continuity of operation. Therefore, the CAMS utilization was increased by 25 percent to account for the spare capacity installed at each RPC.

b. Software (1.2)

This element of the cost estimate is concerned with the cost of further development of the CAMS application after FY 1993. The CAMS/REMIS PMO does not project any funds for this purpose past FY 1993, except those funds provided by organizations wishing to enhance CAMS to support a specific weapon system or activity.

The study team foresees future software development costs in at least the areas of application software and documentation.

(1) **Applications Software (1.2.1)**

Approved CSRDs. CAMS has a backlog of approved functional modifications—Computer System Requirements Documents (CSRDs)—amounting to approximately 30 staff-years of effort (CAMS estimate). This is projected to extend over a three-year period or 10 staff-years per year for three years. This work is expected to be completed by contractor personnel at the rates cited earlier.

Enhanced editing. The study team believes that CAMS must be modified so that the data entry is not only less onerous, but also fully edited, such that erroneous data are refused at the point of entry, and at the time of entry. This enhancement would totally replace the current CAMS edit facility and the process of REMIS responding to the individual bases with error messages an hour or two after the fact, with the expectation of error correction by the users long after they entered the data. This is expected to be an extensive change to CAMS, affecting 20 to 30 percent of the system program modules and as much as 50,000 lines of new and changed code overall. The study team estimates the enhanced data editing and control would require about 15 staff-years of development team effort per year for three years. This enhancement includes the ability to communicate immediately with REMIS for data verification on a fleet-wide basis as necessary. The cost of high-speed communication lines has been included in the recurring hardware cost to accommodate this capability. This work is expected to be completed by contractor personnel at the rates cited earlier.

System Integration and Test. This function is currently performed by the SSC QT&E group at Gunter AFB. The costs projected for this item are a function of the application development effort. The study team estimated that 5 staff-years per year for the first three years would cover the necessary effort. This not only includes integration of the CAMS application into the SBLC and RPC software, but includes distribution to the various user organizations. This work was projected at an annual rate of $55,870 per staff year.

OT&E Support. These are funds to support a CAMS/REMIS OT&E. These costs were based on the $1.4 million cost of the GCSAS OT&E. The total CAMS/REMIS cost was projected to be $2.5 million, half of which is shared by CAMS.

(2) Documentation (1.2.3). This category covers the cost of producing and distributing user manuals. We estimated this as 10 percent of the cost of application software investment. This does not include the cost of other software documentation such

as requirements specifications and design documents; those are already included in the earlier estimates.

2. Recurring Costs (2.0)

a. Program Management (2.1)

(1) Government (2.1.1). This is the projected expense for program management of CAMS. This cost is estimated to be 10 percent of the staff supporting CAMS in development, maintenance, and user support at Gunter SSC.

b. Computer Operations (2.2)

(1) RPC Operations (2.2.1, 2.2.2, and 2.2.3). Using data from both the Air Force Business Case Analysis and the RPC cost projections, costs of the SBLC Regionalization were placed in one of three categories: RPC CONUS Operations, RPC USAFE Operations, or RPC PACAF Operations. Overall personnel staffing data and hardware/software maintenance costs for each RPC were provided by the Gunter SCC.

(2) Base Communications Operations (2.2.4, 2.2.5, and 2.2.6). Costs for personnel and equipment support at the base level also were placed in each of the categories CONUS, USAFE, or PACAF. The cost of the support at each base consists of personnel and equipment maintenance for communications and terminal support. The personnel staffing data were provided by the Gunter SCC, and data from the ACC provided average base communications and terminal support costs.

CAMS's share of the RPC operations and base communication operations costs was determined by using the average CAMS workload as a percentage of the total workload in each of the three RPC organizations. The data are summarized in Table VII-3. (The workload is the percentage utilization of the computer system.)

Table VII-3. CAMS Workload in RPC Organizations

Organization	CAMS Utilization	CPU Utilization	CAMS Workload
CONUS	14.1%	67%	21.0%
USAFE	12.5%	60%	20.8%
PACAF	13.2%	71%	18.6%

c. User Support (2.3)

(1) Field Help Group (2.3.1). The current Field Support Team at Gunter SSC takes problem telephone calls from data base managers and offers help. We projected that this would continue at 11 staff-years per year at a cost of $55,660 per staff-year.

(2) Base Representatives (2.3.2). CAMS data base managers are located at each base to help the users and to serve as a liaison for problems. Historically, an average of 3.5 data base managers have been assigned to CAMS at each base. We projected this would continue at each of 89 bases at a cost of $55,660 per year per representative. Chapter V provides additional information about the CAMS base representatives and data base managers.

(3) Data Base Maintenance (2.3.3). This group is located at Gunter SSC and is charged with supporting the CAMS users and base-level data base managers. Key responsibilities include major data base repair actions, performing system recoveries, investigating and resolving missing data transmissions, supporting CAMS data base managers course development, and performing detailed systems analysis. Six people are projected to provide this service at $55,660 per person per year.

d. Communications (2.4)

(1) RPC High-Speed Links (2.4.1). The RPCs use AFNET communication lines to transmit and receive data from each of the 66 CONUS bases. The cost for these communication lines grows as more bases move into the RPC operation. AFNET is an Air Force set of communication facilities contracted for with various communication line vendors and, in turn, leased or rented to various Air Force organizations. The communication costs projected here were based on the same projections in the Air Force Business Case Analysis for DMRD 924. Since CAMS accounts for about 44 percent of all the transactions between the RPC and the base, the CAMS share of the cost was allocated at 44 percent of the cost.

(2) High-Speed REMIS Link (2.4.2). The study team is projecting the cost of a high-speed (56 Kbps) line from each RPC to REMIS to provide the high-speed turnaround needed for the enhanced data-editing function previously outlined. A monthly rate of $3,500 for each RPC was assumed.

e. Software Maintenance (2.5)

(1) Applications Software (2.5.1). This cost element provides funds for the maintenance of CAMS software. Software maintenance includes correcting and testing

software errors reported by users (Discrepancy Reports or DIREPs), making modifications to the CAMS data base to enhance performance, or add/correct data relationships. Recent CAMS history indicates that about 40 percent of the CAMS staff (45 staff members) are needed to address the current maintenance workload. The study team estimates that this level of effort will be required for the foreseeable future. Since CAMS consists of approximately 1.1 million lines of unique source code, this results in the maintenance of 24,961 unique lines of source code per staff year. This is in line with typical industry averages for data base applications, which vary between 20,000 and 32,000 unique lines of source code per staff year.[1] This work will be performed by a mixture of military and civilian personnel at an average rate of $55,660 per year.

(2) System Integration and Test (2.5.2). This function is performed by the QT&E group at the Gunter SSC (about 75 persons in total). The cost projections were based on a prorated share of the current QT&E support. We estimated nine of the QT&E personnel would be required for maintenance support at a cost of $55,660 per staff-year.

(3) Data Base Management (2.5.3). This effort is staffed by the CAMS organization at the Gunter SSC and includes making modifications to the CAMS data base to enhance performance, or add/correct data relationships by making data base schema modifications. The study team estimated this effort to require four experienced data base analysts at an average rate of $55,660 per year.

(4) Documentation (2.5.4). These funds include resources to modify and update the software documentation in accordance with the changes due to the software and data base maintenance. This was estimated to require five staff-years per year.

f. Training and Travel (2.6)

Training and travel costs of the CAMS users are incurred by the individual bases and were not included in our estimate. The CAMS base representatives will require training on a continuous basis as personnel are reassigned. The training and travel costs are estimated to be 2 percent of the funds under the control of CAMS management.

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[1] Boehm, B.W., *Software Engineering Economics*, Prentice-Hall, 1981, p. 541.

D. COST ESTIMATE FOR REMIS

1. Assumptions

The cost analysis for REMIS is summarized in Table VII-4. The numbers shown in parentheses in the subsections that follow correspond to the numbers to the left of the cost categories in the table. The cost analysis assumed that REMIS will continue to be maintained by Litton Computer Services (LCS) at their facility in Dayton, Ohio. IDA added investment dollars to address two major problems with the system. One problem was slow performance in generating reports. We assumed that performance must be addressed via additional hardware and via software rewrites. A second area of improvement is to expand the scope of data that can be accessed through REMISTALK. The cost to address both of these issues is included in the cost element dealing with nonrecurring software costs (1.2).

REMIS was originally projected to reach MAISRC Milestone III approval in September 1993. According to the REMIS Program Director, the date for Milestone III approval is now projected for October 1994, with full operational capability (FOC) planned for January 1995. The cost estimates reflect this latest schedule.

2. Sources of Information for REMIS Cost Estimates

The IDA team consulted several sources of information in preparing the cost estimates for REMIS. Detailed information was available from the Program Office Estimate (POE) and Independent Cost Estimate (ICE) prepared for the MAISRC Milestone III. More recent cost projections were obtained from LCS. Discussions by telephone and in person were held with members of the REMIS Program Office as well as with Litton personnel. Our general approach was to take data from these sources as inputs to the cost analysis. For most cost categories, we estimated the costs independently as well.

3. Nonrecurring Costs

The nonrecurring costs are divided into hardware, software, communications, training support for OT&E, and security. They are discussed in that order.

a. Hardware (1.1)

(1) Mainframes (1.1.1). In order to adequately address REMIS's performance problems, it is IDA's judgment that another Tandem mainframe will be needed. We assumed a 12-processor machine equivalent to HQ1 for $5 million. This estimate includes

Table VII-4. Cost Estimate for REMIS

	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
		Cost in Millions of 1994 Dollars										
1.0	Nonrecurring Costs											
1.1	Hardware											
1.1.1	Mainframes	5.00			6.00				1.31			12.31
1.2	Software											
1.2.1	Applications Software											
	Performance Improvement	1.99	1.99	1.99								5.97
	REMISTALK Improvement	1.32	1.32	1.32								3.96
1.2.2	Data Base Initialization	1.99	1.32									3.31
1.2.3	Documentation	0.53	0.46	0.33								1.32
1.3	Communications											
1.4	User Training		0.25	0.25								0.50
1.5	Support of OT&E	1.40			1.25							2.65
	Nonrecurring Subtotal	12.23	5.34	3.89	7.25	0.00	0.00	0.00	1.31	0.00	0.00	30.02
2.0	Recurring											
2.1	Program Management											
2.1.1	Government	1.52	1.47	1.32	0.91	0.91	0.91	0.91	0.91	0.91	0.91	10.65
2.1.2	Contractor	0.72	0.70	0.63	0.43	0.43	0.43	0.43	0.43	0.43	0.43	5.07
2.2	Computer Operations											
2.2.1	Central Computer											
	Operational Staff	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	14.70
	Hardware, Software, and Utilities	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	6.30
2.2.2	ALCs											
	Operational Staff											
	Hardware, Software, and Utilities	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	2.70
2.3	User Support	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	10.60
2.4	Communications	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.55
2.5	Software Maintenance											
2.5.1	Applications Software	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97	39.70
2.5.2	Data Base Management	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	13.20
2.5.3	Documentation	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	2.65
2.6	Training and Travel	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	5.55
2.7	Continuity of Service											
	Recurring Subtotal	11.94	11.86	11.64	11.03	11.03	11.03	11.03	11.03	11.03	11.03	112.68
	Total	24.17	17.21	15.53	18.28	11.03	11.03	11.03	12.34	11.03	11.03	142.70

the mainframe, disk storage, control units, and a communications processor. A $1.31 million upgrade is included in the estimate after seven years (assuming a 20-percent compound annual cost reduction).

We are also assuming there will be an upgrade of all other Tandem mainframes in FY 1996 at a total cost of $6 million.

b. Software (1.2)

(1) Applications Software (1.2.1). This category contains the estimated cost for additional work that in IDA's judgment is necessary to bring REMIS up to an acceptable level of operational performance.

Performance Improvement. This cost element covers work needed to reduce the overhead associated with system-to-system input (SSI) and the network control system (operations overhead) so that additional resources will be available for report-generation. This will entail a great deal of performance measurement and analysis and some software re-design and re-coding. We estimated 15 staff-years for each of three years at $132,480 per staff-year resulting in an total estimated cost of $1,987,200 per year.

REMISTALK Improvement. This cost element encompasses work to expand the scope of REMISTALK and reduce the time required to access data. The problems and improvements needed are discussed at length in Chapter V. We estimated 10 people for three years at a cost of $1,324,800 per year.

(2) Data Base Initialization (1.2.2). Once REMIS reaches FOC, the GCSAS subsystem will contain configuration data on all Air Force weapon systems. Effort will have to be expended to load the appropriate configuration tables into the data base. According to Litton and the REMIS PMO, this will be done by existing Air Force personnel (equipment specialists) residing at the Air Logistics Centers (ALCs) for existing weapons systems. For new weapon systems, the tables will be loaded by personnel in the SPOs and by contractors. As far as we could determine, no funding has been set aside for this task, but it is work that will have to be done.

Even though Air Force personnel will be loading the configuration tables, we expect it will be necessary for personnel from Litton to help ensure that the information is gathered and entered accurately. This will require skilled engineering personnel who understand the configuration issues related to specific weapon systems and their implications for the REMIS data base. Because this information is critical and has proved to be difficult to gather in the past, we assume a total of 15 staff-years during FY 1994 and 10

staff-years during FY 1995 to assist in gathering this information. The estimated costs per year are as follows:

FY 1994: 15 staff years at $132,480 per year = $1,987,200 and

FY 1995: 10 staff years at $132,480 per year = $1,324,800.

(3) Documentation (1.2.3). This category covers the cost of producing and distributing user's manuals. We estimated costs at 10 percent of the application software investment. This did not include the cost of other software documentation such as requirements specifications and design documents; those were included in the previous estimates.

c. Communications (1.3)

The costs of leasing communications lines from the ALCs to Litton's facility in Dayton is included under recurring costs.

d. User Training (1.4)

According to Litton, there are no funds budgeted for user training. Litton estimated that there are approximately 1,100 users to be trained on GCSAS. We estimated $250,000 during FY 1995 and FY 1996 for preparation and delivery of training at user sites.

e. Support for OT&E (1.5)

GCSAS is currently undergoing an operational test and evaluation (OT&E) in preparation for the MAISRC Milestone III. This cost category covers the effort expended by the PMO and Litton in support of that effort. We estimate the cost of that effort at $1.4 million.

We have added an additional $1.25 million in FY 1997 for the REMIS PMO and Litton support of a combined CAMS/REMIS OT&E. We assumed that the CAMS/REMIS OT&E will not begin until the needed improvements are made to both CAMS and REMIS.

4. Recurring Costs (2.0)

The recurring costs are divided into program management, computer operations, user support, communications, software maintenance, training and travel, and continuity of service. They are discussed in that order.

a. **Program Management (2.1)**

(1) Government (2.2.1). Costs for the government program management are estimated at 10 percent of total contractor labor (including contractor program management).

(2) Contractor (2.2.1) Costs for contractor program management are estimated at 5 percent of total contractor labor.

b. **Computer Operations (2.2)**

(1) Central Computer (2.2.1). The IDA team estimated that a total of 19 personnel will be required over three shifts to operate the Tandem computers located in Dayton. Assuming an average burdened staff-year of $77,280, the total is $1,468,320 per year.

Hardware, Software, and Utilities covers the cost of maintenance for the processors at Litton's facility in Dayton. It includes $320,000 per year for maintenance of HQ1 and HQ2 plus an additional $220,000 per year for maintenance of the additional mainframe (HQ1 equivalent). This category also includes an estimate of $91,000 per year for system software and utilities.

(2) ALCs (2.2.2). The Tandem processors at the Air Logistics Centers are operated in a "lights out" mode from the Network Control Center (NCC) in Dayton. For that reason, no costs were included in the operational staff category.

Maintenance of the 13 Tandem processors operating at the ALCs was estimated at $235,000 per year. We also added $39,000 for system software and utilities.

c. **User Support (2.3)**

User support takes the form of phone operators at the Network Control Center (NCC) in Dayton, Ohio, plus technical analysts to help resolve user problems. The analysis assumes a total of six phone operators providing 24-hour-a-day coverage at a burdened rate of $30 per hour plus 15 percent for G&A plus fee. That totals $34.50 or $66,240 per operator per year. The analysis also assumes five technical analysts at a burdened rate of $132,480 per year. The total cost of user support is $1,059,840 per year.

d. **Communications (2.4)**

This category covers the cost of leasing communications lines between each of the ALCs and the LCS facility in Dayton. Based on information provided by LCS, the communications charges are estimated at $155,000 per year.

e. Software Maintenance (2.5)

(1) Applications Software (2.5.1). The cost of maintaining the application software was estimated assuming that 25,000 lines of code can be maintained per staff-year. According to LCS, REMIS contains 736,000 lines of COBOL code (including declarations and excluding comments). Dividing 736,000 by 25,000 gives 29.44 staff-years, which was rounded up to 30. Assuming 30 people at $132,480 per year gives an annual cost of $ 3,974,400.

(2) Data Base Management (2.5.2). The information associated with the complex weapon systems supported by REMIS is constantly evolving as the approved and actual configuration changes, as technical orders are issued, and so on. This category covers the resources required to keep the data base current as well as normal data base maintenance. We estimated 10 data base analysts at $132,480 per year for a total of $1,324,800.

(3) Documentation (2.5.3). The recurring documentation costs represent changes that must be made to documentation whenever modifications are made to REMIS that affect the users. These could be modifications as a result of resolving a problem report or modifications that represent functional enhancements. We estimated them at 5 percent of the cost of application software maintenance.

f. Training and Travel (2.6)

This category covers the cost of on-going user training plus general travel. These costs have been estimated at 10 percent of the cost of application software maintenance.

g. Continuity of Service (2.7)

In the event of a catastrophe (e.g., fire or tornado) in Dayton that destroyed the computer facilities, LCS plans to switch processing to the Oklahoma City ALC, which has five processors compared to the other four ALCs with two processors each. REMIS would operate there in a degraded mode until additional processors could be obtained. (By way of comparison, REMIS operates on a total of 20 processors on HQ1 and HQ2.) Because REMIS is not critical for day-to-day base-level flight operations, we viewed this as an acceptable backup plan and added no costs to this category.

h. Security

A Tandem product called SAFEGUARD will enable REMIS to meet Category 2 security requirements. The cost for this product for HQ1, HQ2, and the processors at the

ALCs is $28,284 per year. Because we do not have comparable information for all systems and because the cost is so small, we deliberately excluded security costs from Table VII-4.

E. COST ESTIMATE FOR TICARRS

1. Assumptions

Our cost analysis was based on the assumption that TICARRS will continue to be maintained by Dynamics Research Corporation (DRC) in Andover, Massachusetts. This need not be the case. TICARRS could be taken in-house by the Air Force or operated by another contractor, but it would be difficult to assess the risk or estimate the costs of expanding TICARRS under such circumstances.

We assumed that all base-level input will be direct to TICARRS rather than through CAMS. The base-level daily transaction rate will be less than the FY 1993 averages for the next ten years due to base closures and unit de-activations.

DRC will provide domestic communications; the Air Force will provide overseas communications. The domestic communications prices were based on Sprint rates in use by DRC. It is feasible to use the AFNET instead; however, we did not evaluate the cost of the AFNET services. (Based on the AFNET costs for the RPCs, it is likely that the monthly rates would decrease compared to the Sprint charges). Data Communication Processors (DCP), terminals, and printers currently at the bases would be used, and the staff now in the Air Force plan would support the equipment. TICARRS will be expanded to include all Air Force weapon systems except strategic airlift aircraft (which are covered by CAMS). This expansion will include a total of 44 types of aircraft, missiles, and 1,700 communication-electronics end items. A total of 254 units (squadrons) will change over from CAMS to TICARRS. The completed cost element structure is shown in Table VII-5. As before, the numbers to the left of the cost categories are noted in parentheses in the discussion of cost that follows.

In order to expand TICARRS to cover all weapon systems now covered by CAMS and 89 Air Force bases, there are several major steps that must be taken:

- Additional hardware must be purchased in order to handle the greatly increased demands on processing and data storage.

Table VII-5. Cost Estimate for TICARRS

	Category of Cost	Cost in Millions of 1994 Dollars										
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hardware											
1.1.1	Mainframes			3.08	2.46						1.06	6.60
1.2	Software											
1.2.1	Application Software											
	Functional Enhancements		1.81									1.81
	REMIS Interfaces		1.29									1.29
	Load REMIS Data				1.32							1.32
1.2.2	Data Base Initialization		1.65	6.59	1.65							9.89
1.2.3	Documentation		1.76	0.66	0.30							2.72
1.3	Communications											
1.3.1	Hardware			0.05								0.05
1.4	Training/Unit Activations											
1.4.1	Site Surveys			0.27	0.43							0.70
1.4.2	Load CAMS Data			1.89	2.96							4.85
1.4.3	User Training			0.96	1.50							2.46
1.4.4	Resolve DIREPS			1.77	2.77							4.54
1.4.5	Short-Term Support			0.48	0.75							1.23
	Travel and Living (Site Visit)			0.05	0.08							0.13
1.4.6	Travel and Living (Training)			0.42	0.65							1.07
1.4.7	Travel and Living (Short-Term)			0.21	0.33							0.54
1.5	Support OT&E		1.25	1.25								2.50
	Nonrecurring Subtotal	0.00	7.76	17.68	15.20	0.00	0.00	0.00	0.00	0.00	1.06	41.70
2.0	Recurring Costs											
2.1	Program Management											
2.1.1	Government	0.71	1.20	2.43	2.66	1.50	1.50	1.50	1.50	1.50	1.50	16.02
2.1.2	Contractor	0.34	0.57	1.19	1.32	0.72	0.72	0.72	0.72	0.72	0.72	7.71
2.2	Computer Operations											
2.2.1	Central Computer											
	Computer Usage	0.50	0.50									1.00
	Operational Staff	1.68	1.68	1.95	2.55	2.55	2.55	2.55	2.55	2.55	2.55	23.17
	Hardware, Software, and Utilities	0.72	0.72	0.72	1.45	1.45	1.45	1.45	1.45	1.45	1.57	12.43

Table VII-5. Cost Estimate for TICARRS (Continued)

	Category of Cost	Cost in Millions of 1994 Dollars										
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
2.2.2	Base Comm. Ops. CONUS											
	Civilian and Military Personnel			1.84	5.52	7.36	7.36	7.36	7.36	7.36	7.36	51.54
	Hardware, Software, and Utilities			0.54	1.62	2.16	2.16	2.16	2.16	2.16	2.16	15.13
2.2.3	Base Comm. Ops. USAFE											
	Civilian and Military Personnel			0.42	1.26	1.68	1.68	1.68	1.68	1.68	1.68	11.79
	Hardware, Software, and Utilities			0.11	0.34	0.46	0.46	0.46	0.46	0.46	0.46	3.20
2.2.4	Base Comm. Ops. PACAF											
	Civilian and Military Personnel			0.13	0.38	0.51	0.51	0.51	0.51	0.51	0.51	3.57
	Hardware, Software, and Utilities			0.06	0.19	0.25	0.25	0.25	0.25	0.25	0.25	1.77
2.3	User Support	2.63	2.63	5.73	7.66	8.05	8.05	8.05	8.05	8.05	8.05	66.95
2.4	Communications	0.56	0.56	0.87	1.41	1.41	1.41	1.41	1.41	1.41	1.41	11.85
2.5	Software Maintenance											
2.5.1	Application Software	2.25	2.25	2.25	2.77	2.77	2.77	2.77	2.77	2.77	2.77	26.14
2.5.2	Data Base Management	1.32	1.32	1.85	2.65	2.65	2.65	2.65	2.65	2.65	2.65	23.04
2.5.3	Documentation	0.18	0.18	0.21	0.27	0.27	0.27	0.27	0.27	0.27	0.27	2.46
2.6	Training and Travel	0.37	0.37	0.43	0.57	0.57	0.57	0.57	0.57	0.57	0.57	5.16
2.7	Continuity of Service			0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.44
	Recurring Subtotal	11.27	12.00	20.90	32.80	34.54	34.55	34.55	34.55	34.55	34.67	284.37
	Total	11.27	19.76	38.58	48.00	34.54	34.55	34.55	34.55	34.55	35.73	326.07

- Enhancements will be required to the application software. As discussed in Chapters V and VI, eight functional enhancements have been identified.
- The data base must be initialized for each of the weapon systems and associated trainers and simulators, and for communications-electronics.
- Data must be loaded from REMIS.
- Additional communications must be added.
- A total of 254 units must be activated and users trained.

The effects of these steps on cost are discussed in the subsections on nonrecurring and recurring costs that follow.

In estimating the nonrecurring costs, we assumed the schedule that was discussed in Chapter VI. Specifically, we assume that, as an Air Force standard system, TICARRS would be subject to an Operational Test and Evaluation (OT&E) and to MAISRC approval. The cost analysis for expanding TICARRS assumes that a contract to perform the work would be awarded by 1 November 1994. Eight months would be spent in enhancing the functionality of TICARRS to take over the functions of CAMS/REMIS. In addition, in preparation for the OT&E, the data base would be initialized for two weapon systems and CAMS data from one base would be loaded onto TICARRS. This would be accomplished by 1 October 1995. The OT&E would then occur during October through December at the one base for the two weapon systems. Data base initialization and data loading would occur throughout the Air Force during FY 1996 and FY 1997.

There are two areas where delays in the assumed schedule may occur: delays in the acquisition process and delays in the nonrecurring development program. We have included a sensitivity analysis to address this issue.

2. Nonrecurring Costs (1.0)

a. Hardware (1.1)

For TICARRS to provide the same or better service to all Air Force users as CAMS/REMIS does, hardware must be added. The current TICARRS hardware is as follows:

- Mainframe: Bull 9094 DPS[2] (36-MIP four-way processor, 192-megabyte RAM).

[2] This mainframe computer is not used full-time to support the TICARRS workload.

- Cost: $3.0 million (1993 cost including mainframe and disk storage).
- Communications Processors: two Unisys DCP-30 processors.
- Communication Lines: 57 lines at 9.6 kilobyte (leased from Sprint).

(1) **Mainframes (1.1.1).** Computer power must be about four times the existing level. Allowing for a 20-percent compound cost-reduction rate through 1996, this requires an investment or nonrecurring cost of $5.54 million. An additional $1.1 million in 2003 is needed for replacement cost.

Historically, the daily transaction rate for CAMS has been 1.1 million transactions per day over an 8-hour period (first shift). An estimated 1.6 million transactions per day are processed over a 24-hour period (based on data collected by USAF SSC over the period January through February 1993 (8 weeks). The daily transaction rate during first shift is expected to drop from 1.1 million to 1.0 million due to the number of base closings planned through 1994. The projected transaction rate is based on the number of bases dropping from 107 to 89.

Data collected by DRC during the TICARRS 92 assessment at Seymour Johnson AFB measured the central processor utilization rates for TICARRS to be:

- 2.54 percent (average) over a 24-hour period to process an average 40,000 transactions,
- 4.60 percent (average) over an 8-hour period (peak) to process an average of 20,000 transactions, and
- 99 percent of TICARRS transactions had response times of less than 3.24 seconds. Assume, therefore, that the central processor is used no more than an average of 65 percent during peak shift in order to achieve a 3-second response time. Keeping the average utilization at 65 percent permits the computer to operate at higher utilization rates for brief periods to work off messages in queues and surges in transaction traffic.

The ratio of average peak utilization to average peak transactions is used to calculate the additional computer use required for 1.0 million transactions processed by all the CAMS installations. Because the Seymour Johnson data indicate that the average number of TICARRS transactions exceed the average number of CAMS transactions by 5.6 percent, we increased the total number of transactions by 5.6 percent to compensate:

1.056 million CAMS transactions (average peak) ÷ 20,000 average transactions (peak) = 52.8;

52.8×4.6 percent = 243 percent utilization.

Total CAMS support requires 243 percent utilization, or 87.4 million instructions per second (MIPS), to support 1.056 million transactions during peak or first shift.

To provide the computing power to support REMIS users, the computer utilization for those REMIS activities not included above were added:

- 2.5 percent utilization for file maintenance, table maintenance queries, error correction and electronic mail;
- 2.5 percent utilization for processing and transmitting data outbound to other systems; and
- 10 percent utilization for user reports.

Thus, the total additional REMIS support is 15 percent.

Total TICARRS power needed to support CAMS/REMIS users is 258 percent (243 percent for CAMS plus 15 percent for REMIS), and the maximum average computer utilization during peak hours is 65 percent.

The increase needed in TICARRS's computer system is: 258 percent + 65 percent = 3.96. Measured in terms of existing computers, TICARRS will need 3.96 × 36 MIPS = 142.8 MIPS.

The cost of the current computer is $3.0 million; however, the 1996 price of the same computer is projected to be $1.536 million (20 percent compound reduction rate) and $1.228 million in 1997. The cost of the computer system was spread over two years to match the growing workload caused by adding bases to the TICARRS system during 1996 and 1997, resulting in a cost of $5.54 million.

b. Software (1.2)

(1) Application Software (1.2.1).

Functional Enhancements. A total of eight functional enhancements have been identified for TICARRS:

- CEMS interface,
- SBSS interface,
- personnel and training,
- aerospace ground equipment (AGE),
- production management (comparable to CAMS 380 screen),
- maintenance snapshot (comparable to CAMS 122 screen),

- automated aircraft forms, and
- Product Quality Deficiency Reports (PQDRs).

Before discussing the estimates for including these functions in TICARRS, it is necessary to discuss lines-of-code counts because they are a major cost driver in the implementation of additional functionality. There is a large discrepancy between the lines-of-code count in TICARRS and the combined count for CAMS/REMIS; this discrepancy has been the impetus for a great deal of debate. The Air Force and LCS make the argument that the number of lines of code required to implement the above functions in CAMS or REMIS will be the number required for TICARRS. We considered these arguments but rejected them because the designs of the systems are vastly different.

CAMS contains 1.1 million unique lines of COBOL code, REMIS contains 736 thousand, and TICARRS contains 417 thousand. On the surface, it appears that TICARRS contains less than 25 percent as much code as CAMS/REMIS. Central to the design of TICARRS is a tool called Middleware, which provides sets of reusable code and program "shells" to handle the common data base functions of displaying information to the user on the screen, updating information in the data base, retrieving information from the data base, and processing user input. The use of Middleware allows much of the functionality of TICARRS to be table-driven. One line of a table can replace many lines of COBOL code. With Middleware, the programmers write only the application-specific code for any given function. It is important to note that the total COBOL for TICARRS (i.e., the COBOL written by the programmers plus the COBOL generated by Middleware) is actually *more* voluminous than CAMS/REMIS (2.44 million lines of COBOL versus 1.84 million for CAMS/REMIS). However, it is the programmer-generated code and not the total COBOL that the programmers have to write and maintain, and that is the lines-of-code count we considered for estimating the effort involved in the functional enhancements.

As an illustration of the differences in lines of code between the systems, we gathered lines-of-code counts for functions implemented in TICARRS and in CAMS/REMIS. Table VII-6 shows these counts for four such functions.

For the above functions overall, there is an approximately 3:1 ratio between the count of programmer-written lines for CAMS/REMIS versus TICARRS. Note that the total COBOL count for TICARRS surpasses CAMS/REMIS.

In estimating the resources required for implementing each of the eight functional enhancements, we looked at the design of TICARRS and at how the enhancements would

be implemented within that design. That is different from how they are or might be implemented within another system.

Table VII-6. Comparison of Lines-of-Code Counts

	CAMS	REMIS	TICARRS	
Function	COBOL Source Lines	COBOL Source Lines	Programmer-Generated Lines	COBOL Source Lines
Auto Debriefing	55,280		16,322	51,339
Equipment Transfer	18,682		6,617	19,473
Utilization Reporting		28,737	5,911	26,762
Inspection/Time Change		5,414	6,928	28,634
Total	73,962	34,151	35,778	126,208
Total CAMS/REMIS	108,113			

Source: The lines-of-code counts for CAMS and REMIS were taken from "Impact Information Regarding FY 93 HAC Report Language on CAMS/REMIS and TICARRS" by Robbins-Gi[illegible] Incorporated, 1992.

As one input to our estimate, we obtained a formal impact analysis for each enhancement from DRC. Each impact analysis included a detailed description of the function to be added, a description of the programs or modules within TICARRS that are impacted, an estimate of the number of lines of code to be added or changed within each module, the layout of all new and modified screens, a description of any changes to the data base, and an estimate of the staff hours required to specify, design, implement, document, and test the enhancement.

Our first step was to evaluate the credibility and reliability of the impact analyses as a basis for estimating. The impact analyses were reviewed by functional analysts from IDA to assess their validity in terms of adequately describing the function to be implemented. Secondly, we evaluated DRC's record in using the impact analyses as a basis for resource estimates. We obtained historical data from DRC, which allowed us to compare their estimates, based on similar types of impact analyses, with actual hours charged to the Air Force. Over a total of 64 efforts, which included a mix of functional enhancements, performance enhancements, and defects corrections, 18 of the 64 had been under-estimated by DRC and 46 had been over-estimated. On average, DRC completed the work with 13 percent fewer staff hours than estimated.

Having established that the impact analyses were adequate from a functional standpoint and that they served as a basis for accurate resource estimates, we used them to derive lines-of-code estimates for entry into a software cost model, SPQR. This model was chosen because it provides a straightforward means of modeling the enhancements as they

would be implemented in TICARRS. In deriving the estimates, we entered three different lines-of-code counts:

- the size of the base code involved in each of the enhancements (The base code encompasses any and all modules for which any lines are added or modified. That code is relevant because it must be handled and tested, thereby adding to the workload.),
- the size of reused code, in this case a count of the lines of the Middleware shells, and
- the size of the new or changed lines.

Table VII-7 shows these three counts for each enhancement. The table also shows the number of staff hours estimated by the model for each enhancement. The total costs for the functional enhancements were estimated by multiplying the number of staff hours estimated by SPQR (23,917) by $69 per hour for a total of $1,650,273. An additional 10 percent was added for generating or modifying the Middleware tables, for a total of $1,815,300.

Table VII-7. Estimated Lines of Code and Staff Hours Required for Functional Enhancements

Functional Enhancement	Base Code Size	Reused Code Size	New/Changed Code Size	Estimated Staff Hours
Production Management	117,755	14,781	4,215	2,496
CEMS Interface	75,440	7,669	5,540	3,338
SBSS Interface	135,804	19,329	12,860	8,322
Personnel/Training	0	6,462	7,950	4,746
Maintenance Snapshot	3,318	681	595	320
Automated Aircraft Forms	39,470	9,358	5,110	2,987
PQDR	26,119	4,435	1,503	878
AGE	25,074	6,389	1,450	830
Total			39,223	23,917

We assumed that all eight enhancements will be carried out in FY 1995. There do not appear to be sequential dependencies among them, so we assumed that they can be implemented in parallel.

REMIS Interfaces. Although TICARRS would replace a number of existing systems (as will REMIS), thirteen software system interfaces would not be replaced. Programming effort will be necessary to accept data from those systems and to provide them with the data they need, in the format they need. The thirteen systems are as follows:

- D086A—Individual Aircraft Service Life Monitoring System,

- K002—Peacetime Programming Computational System,
- K008—Aerospace Vehicle Percent Flying Hour Program System for AFMC,
- G081—CAMS for Airlift,
- D087F—Weapon System Management Information System,
- D160B—Visibility/Management of Operation Support Cost System,
- D165B—Aerospace Vehicle and Mission Capability System,
- D200—Requirements Data Bank,
- G001C—Contractor and Depot Maintenance Data Collection System,
- D043—Master Item Identification Control System,
- D038—Precision Measurement Equipment Calibration Interval Analysis,
- D075—Logistics Management Data Bank, and
- G012—Computational Support for Create Engineer Support.

Each interface was estimated to require .75 staff-years to develop at $132,480 per staff year. We assume that thirteen interfaces would be implemented in FY 1995.

Load REMIS Data. This category covers the cost of loading historical data from REMIS into TICARRS. We assume that this will be done electronically with some manual effort required to resolve data-loading problems. Programming effort must be expended to write code to translate the REMIS files into a format that can be read by TICARRS. We estimated ten staff-years at $132,480 per staff-year.

c. Data Base Initialization (1.2.2)

The data base must be initialized for each new weapon system. The cost will vary with the complexity of the system and with the number of serially tracked items. The following information must be added to the data base for each new weapon system:

- description of equipment:
  - work unit codes (for test stations as well as aircraft),
  - part numbers,
  - serial numbers, and
  - hierarchical relationship between WUCs;
- approved configuration;
- quantity of components per weapon system;
- identify serially tracked items;

- phase inspections;
- open TCTOs;
- special inspections;
- location of equipment;
- contractors requiring access; and
- PQDR information.

Estimates for each weapon system are shown in Table VII-8. These include aircraft, trainers, and simulators. These estimates were derived by estimating the staff-hours required for each weapon system, taking into account the complexity of the avionics and the automatic test equipment, the complexity of possible missions, and the complexity of the configuration to be tracked. We included additional costs for variations in block numbers and model designations. Note that the TICARRS data base has already been initialized to a large extent for the F-16, F-15, and F-117, with the result that the estimated cost for these systems is less than would be expected for a system that was not in the data base. We also included an estimate for communications-electronics. We assumed data base initialization would average $1,000 for each of the 1,700 types of communications-electronic equipment for a total of $1,700,000. The total cost of data base initialization was estimated to be $9,858,000.

We assumed that data base initialization will begin in the fourth quarter of FY 1995 and continue through the first quarter of FY 1997.

d. Documentation (1.2.3)

This category covers the cost of producing and distributing user's manuals and training materials for all equipment and for all bases. We estimated this as 10 percent of the cost of application software investment. This does not include the cost of other software documentation such as requirements specifications and design documents; those are already included in the previous estimates. However, it does include a one-time charge to bring the system documentation up to current DoD standards (DOD-STD-7935). This latter effort would include generating various deliverables as well as modifying the format of existing documentation. We are estimating a total of 10 staff-years during FY 1995 at $132,480 per staff year for a total of $1.32 million.

Table VII-8. Data Base Initialization Costs

Weapon System	Delta	Initialization Costs (Thousands of Dollars)
F-16C/D		175
Block 40	0.1	18
Block 50	0.1	18
F-15		145
F-15A/B	0.1	15
F-15C/D	0.1	15
F-15E	0.1	15
F-117		80
F-4		275
A-10		275
F-111		275
EF-111	0.5	138
B-1		500
B-2		500
B-52G		275
B-52H	0.2	55
KC-10		120
KC-135E		120
KC-135R	0.25	30
EC-135	0.25	30
RC-135	0.25	30
VC-137	0.25	30
T-1A		100
T-37		100
T-38		100
T-39		100
T-41		100
T-43		100
C-9		160
C-12		160
C-20		160
C-21		160
C-23		160
C-26		160
C-130E		225
C-130B	0.1	23
C-130H	0.1	23
HC-130N/P	0.1	23
WC-130E/H	0.1	23
MC-130E/H	1	225
AC-130A/H	1	225
C-141		160
E-3		200
E-4		225
E-8		150
H-1		200
H-3		200
H-53		200
MH-53	1	200
H-60		200
MH-60	1	200
UH-60	0.1	20
Trainers/ Simulators		742
Comm.-Electronics		1,700
Total		9,858

e. Communications (1.3)

(1) Hardware (1.3.1). Communications hardware must be increased to support the increased number of daily transactions. This increased transaction rate may be handled by adding three Memotec High-Speed Packet Switch central processing units and a memory upgrade to each of two DCP-30 processors. The cost of additional communications hardware is $50,000.

There is no additional nonrecurring cost for communication lines because Sprint lines are used and Sprint does not charge for installation on new lines.

f. Training/Unit Activations (1.4)

Site activation is carried out for each unit or squadron. The unit activation costs are a potentially important cost driver because they are multiplied 254 times. For purposes of the analysis, 145 of these units are classified as high complexity, 80 as medium, and 29 as low. Activation costs were calculated by identifying the steps involved, estimating the number of staff-weeks for each step at each complexity level, and multiplying by the number of units. Our estimates of the resources required for each of the steps were based on the experience at Seymour Johnson. The analysis assumes that site activation will be carried out over a 19-month period, beginning 1 March 1996 and ending 30 September 1997. For each of the following steps, we assumed that 39 percent of the dollars would be spent in FY 1996 and 61 percent in FY 1997.

(1) Site Surveys (1.4.1). Several major activities are involved in activating a given unit. The first activity is to conduct a site visit in order to meet with unit personnel, to identify all terminals and printers by work location, and to assess the adequacy of the communications facilities. For sites that do not have access to external communications, a line will be installed. Sprint, the current carrier for TICARRS, does not charge for installation. We assumed that each unit, regardless of complexity, would require an average of 40 hours to conduct the site survey at the $69 per hour rate. This implies a cost of $2,760 per unit. The total across all 254 units is $701,040.

(2) Load CAMS Data (1.4.2). A second major activity involves loading the CAMS data for a given unit into TICARRS. Some CAMS data at Seymour Johnson were found to be in error, especially in terms of configuration. TICARRS has configuration edits, requiring that these data be cleaned up before they can be entered into the system. In some cases, this can be done via software; in other cases, it has to be done manually. These kinds of problems are likely to persist for each unit so we do not expect them to decrease significantly across units. The cost estimate assumes that two staff-months (160 hours per

month or 320 hours total) per unit will be required to load the data from CAMS for high-complexity units, 1.5 staff-months for medium-complexity units, and 1 staff-month for low-complexity units.

The cost calculations are shown below:

145 units × 320 hours per unit = 46,400 hours at $69 = $3,201,600,

80 units × 240 hours per unit = 19,200 hours at $69 = $1,324,800, and

29 units × 160 hours per unit = 4,640 hours at $69 = $320,160

The total is $4,846,560.

(3) User Training (1.4.3). Our estimates for user training were two people for three weeks per unit (240 hours), regardless of complexity. At $40.25 per hour, this comes to $9,600 for one unit and $2,453,640 across all 254 units.

(4) Resolve DIREPS (1.4.4). There were approximately 150 Difficulty Reports (DIREPs) resulting from the Assessment at Seymour Johnson or an average of 50 per unit. Approximately 135 of these resulted in changes to the application software or the data base (e.g., adding a specific part number/serial number combination), or in resetting of system parameters (e.g., to allow printing to a desktop printer). These DIREPs averaged 20 hours each to research, resolve, and re-test the affected part of the system and make any necessary changes to the user documentation. Many of these DIREPs represent "bugs" in the application software or the data base. We expected that the DIREPS would decline exponentially for any given weapon system over units (i.e., they will start out high and then drop quickly). This steep decline is typical of many fielded applications. For high-complexity units, we assumed an average of 15 DIREPS per unit. We assumed an average of 11 DIREPS for medium-complexity units and an average of 8 for low-complexity units. The breakout is as follows:

145 units × 15 DIREPS per unit × 20 hours at $69/hour = $3,001,500,

80 units × 11 DIREPS per unit × 20 hours at $69/hour = $1,214,400, and

29 units × 8 DIREPS per unit × 20 hours at $69/hour = $320,160.

The total across all 254 units is $4,536,060.

(5) Short-Term Support (1.4.5). Extra support from DRC site representatives must be available during the first few weeks. We are assuming one extra site representative (at $40.25 an hour) per unit for three weeks. This yields a total of $1,229,868.

Travel and Living (Site Visit). Travel and living expenses for the site visits were calculated using $100 day for 5 days per unit. This comes to a total of $127,000.

(6) Travel and Living (Training) (1.4.6). Travel and living expenses for the initial training were calculated using $100 day for three weeks for two people. This comes to $4,200 per unit or $1,066,800 total.

(8) Travel and Living (Short-Term) (1.4.7). Travel and living expenses for the short-term support are estimated for each unit at $100 a day for three weeks. The total cost for 254 units is $533,400.

g. Support OT&E (1.5)

This category covers support for an operational test and evaluation in preparation ior the MAISRC Milestone III. We estimated a total of $2.5 million spread out equally over FY 1995 and FY 1996.

2. Recurring Costs (2.0)

a. Program Management (2.1)

(1) Government (2.1.1). Costs for the government program office were estimated to be 10 percent of total contractor labor (including contractor program management).

(2) Contractor (2.1.2). Costs for contractor program management were estimated to be 5 percent of total contractor labor.

b. Computer Operations (2.2.)

(1) Central Computer (2.2.1). The cost estimates associated with the central computer are broken down into computer usage, operational staff, and hardware, software, and utilities.

Computer Usage. The existing computer installed at DRC will be used to continue the current support provided for the F-16 and other aircraft. This cost will be terminated with the purchase of computers for TICARRS in 1996.

Operational Staff. The central computer operational staff cost includes all the personnel required to operate the central computer systems, network management, technical support, and clerical help for a three-shift-per-day operation. This is estimated to be 33 people at $77,280 per year for an annual cost of $2,550,240 once TICARRS is deployed.

Hardware, Software, and Utilities. The cost for hardware maintenance and software licensing is estimated to be 25 percent of the cost of the system hardware.

(2) Base Communications Operations (2.2.2, 2.2.3, and 2.2.4). This is the allocated cost for maintenance and support of the base-level terminals and communication equipment. The annual cost is the same as that allocated to CAMS, once TICARRS is fully deployed. The cost to TICARRS at the end of the measurement period is less than CAMS because TICARRS does not start to provide service until 1996.

The base communications operations costs are identified by CONUS, USAFE, and PACAF organizations. These are the same costs as were applied to CAMS. (See cost description for CAMS for more information.)

Civilian and Military Personnel. This is the cost of personnel to operate and maintain the Data Communication Processor (DCP), communication equipment, and terminals at each of the bases allocated to TICARRS.

Hardware, Software, Utilities. This is the estimated cost of maintenance of the base level communication and terminal equipment allocated to TICARRS.

c. User Support (2.3)

User support for TICARRS takes the form of site representatives residing at the bases. We estimated one site representative for each of 89 bases by the end of FY 1997. The cost estimate begins with 34 at the beginning of FY 1996 (the current number) and increases to 89 through FY 97. We also included two site representatives for each of the five ALCs (for a total of ten) beginning in FY 1996. Assuming a fully-burdened hourly rate of $40.25 and 1,920 hours per year, the annual cost for the site representatives was estimated as follows:

- FY 1994 (34 site representatives) = $2,627,520,
- FY 1995 (34 site representatives) = $2,627,520,
- FY 1996 (average of 59 site representatives + 10 ALCs) = $5,332,320,
- FY 1997 (average of 84 site representatives + 10 ALCs) = $7,264,320, and
- FY 1998 (straight-lined at 89 site representatives + 10 ALCs) = $7,650,720.

We have also included three full-time personnel to staff a help desk at Andover beginning in FY 1996 at $69 per hour for a total of $397,440.

d. Communications (2.4)

The estimated yearly communication line charges are $1.67 million for lines linking the Air Force bases with the TICARRS system at Andover, Massachusetts.

Our estimate is based on a total of 89 bases (66 CONUS and 23 OCONUS), 57 of which are in communication now (45 CONUS and 12 OCONUS). The CONUS bases will need to be upgraded from a 9.6-kilobytes per second (Kbps) to a 19.2-Kbps line. The remaining 32 bases (21 CONUS and 11 OCONUS) have no communication links and will need 19.2-Kbps lines. In addition, Andover (DRC) will require two additional 56-Kbps lines to handle additional traffic. (Fifteen F-16 and F-15 AFR and ANG bases now share active Air Force facilities.)

The costs to upgrade from 9.6 Kbps to 19.2-Kbps is $430 per month. Sprint rates are as follows:

- a 19.2-Kbps line is $1,145 per month and
- a 56-Kbps line is $3,500 per month.

The calculation of the CONUS plus OCONUS communications costs involves:

- 45 CONUS and 12 OCONUS sites at $470 per month: $321,480 per year,
- 21 CONUS and 11 OCONUS sites at $1,145 per month $439,680 per year,
- two lines at $3,500 per month: $84,000 per year,
- current annual cost of 57 sites: $562,992 for 1994 and 1995 only, and
- total projected annual communication costs: $1,408,152 per year.

This cost is fully realized by 1998 when TICARRS is fully deployed.

e. Software Maintenance (2.5)

(1) Applications Software (2.5.1). The dollar values shown for FY 1996 and FY 1997 do not include the cost of resolving DIREPS that are reported during site activation; those were included above. The maintenance assumed in this cost element involves the steady-state tasks of responding to other DIREPS, development of minor enhancements, and so on.

The estimate assumes that 25,000 lines of code can be maintained per staff year. TICARRS is currently 417,000 lines of unique COBOL code (including declarations and executable lines, excluding comments). We estimated 17 staff years for FY 1994 through FY 1996.

Once the functional enhancements are in place, those lines of code must be maintained as well. We assumed two additional maintainers for the additional 39,000 lines of programmer-generated code for a total of 19. At $132,480 per burdened staff-year, we estimated $2,517,120. We then added 10 percent for maintenance of the Middleware tables for a total of $2,768,832 per year.

(2) Data Base Management (2.5.2). This task involves the changing of the data base structure for performance purposes, balancing the distribution of data across the data storage devices, and repairing/correcting the data base in the case of damage by a software defect. This also includes maintaining current configuration data for each weapon system. The study team estimated this effort would require 8 experienced data base managers in FY 1994, growing to 14 in FY 1996 and to 20 in FY 1997 for a total of $2,649,600 per year.

(3) Documentation (2.5.3). The recurring documentation costs represent changes that must be made to documentation whenever modifications are made to TICARRS that impact the users. These could be modifications as a result of resolving a DIREP or modifications that represent functional enhancements. They have been estimated at 5 percent of the cost of application software maintenance.

f. Training and Travel (2.6)

This category covers the cost of periodic training of the site representatives (who, in turn, conduct the user training) and miscellaneous travel to and from Andover to the user sites. These costs were estimated at 10 percent of the cost of application software maintenance.

g. Continuity of Operations (2.7)

This cost item provides TICARRS with the capability to re-establish operation at another site in the event of a catastrophic failure at the TICARRS computer center. For a monthly fee, Dataguard Recovery Services, in Louisville, Kentucky, would guarantee TICARRS with access to an off-site compatible computer system and communication facilities in the event of a disastrous outage at the TICARRS central site. The monthly fee provides for 72 hours testing of the continuity procedures per year. Actual operational usage is not included in the fee except as part of the continuity test. The monthly fee quoted for the TICARRS Bull equipment configurations is $14,600. (See Chapter V for more information about continuity of operations).

F. COST DRIVERS

The cost differences that result from comparing CAMS/REMIS to TICARRS can be understood by identifying and evaluating the cost drivers for the information systems. The following factors greatly affect costs in maintenance information systems:

- volume of application software (developed, maintained) and size and complexity of the data base,
- computer operations,
- user support (both on and off the site), and
- communications.

The cost driver that affects volume of software is measured by lines of codes that must be generated and maintained by the programmers. The other three factors are heavily influenced by the basic architecture of the systems (e.g., central data base versus distributed system versus a base-level replicated system).

Table VII-9 shows a representative annual recurring costs for CAMS, REMIS, and TICARRS that can be attributed to the four major cost factors cited.

Table VII-9. Comparison of Costs Across Systems

	Cost in Millions of Dollars			
Major Factors	CAMS	REMIS	CAMS/REMIS	TICARRS
Volume of Software	$3.5	$5.6	$9.1	$5.7
Computer Operations	$10.1	$2.4	$12.5	$4.0
User Support	$18.4	$1.1	$19.5	$8.1
Communications	$13.5	$0.2	$13.7	$13.8

The table clearly shows that the costs for CAMS/REMIS in three of the categories exceed those for TICARRS. For volume of software, this result is partly attributable to the use of Middleware in TICARRS, which has the significant effect of lowering the programmer-generated and programmer-maintained lines of code relative to CAMS/REMIS. Moreover, CAMS and REMIS are really two systems, requiring a significant amount of computer code that fosters interfaces between them. That would be unnecessary in one system containing the same total functionality.

For computer operations and user support, the cost differences result from the level of effort required to develop, support, and maintain a central data base architecture system such as TICARRS, relative to the base-level replicated system of CAMS combined with cost of supporting a separate REMIS central data base. Much of what is done at each base

for CAMS can be centrally controlled and efficiently undertaken at the TICARRS central site. For example, whereas both CAMS and TICARRS require one site representative for typical user support, CAMS also requires two to three data base managers per base to undertake activities at the base that are performed only once fleet-wide at the TICARRS central site.

The key cost driver is the system architecture—central data base versus one that is replicated for each base. For computer operations and user support, this cost driver results in a cost difference of almost $20 million annually. In addition, because Middleware reduces the value of programmer-operated and -maintained code, associated costs are reduced.

G. COST COMPARISON OF ALTERNATIVES

1. Alternative 1: Enhanced Version of CAMS/REMIS

In this alternative, CAMS/REMIS would continue with the enhancements discussed previously. TICARRS would be phased out beginning at the time of FOC of REMIS (projected for January 1995). Since the weapon systems supported by TICARRS are also supported by REMIS, we assumed that the phasing out could be done quickly. For our analysis, the phase-out would be done over a three-month period (January through March 1995). Thus, TICARRS would operate throughout FY 1994 and through the first six months of FY 1995.

In this alternative, TICARRS would not be expanded but would continue with its current scope and functionality. To estimate the costs of operating TICARRS throughout FY 1994 and the first six months of FY 1995, we used the recurring cost estimates from Table VII-5. The total for TICARRS for FY 1994 is $11,270,000. We assumed 50 percent of this amount would cover the first six months of FY 1995.

The costs of CAMS and REMIS in this alternative are equivalent to the costs estimated for them earlier in this chapter and displayed in Tables VII-1 and VII-4. Table VII-10 shows the costs of Alternative 1.

2. Alternative 2: Enhanced Version of TICARRS

In the second alternative, TICARRS would be expanded in terms of functionality and scope as already described. We estimated that TICARRS would not be completely activated until the end of FY 1997. REMIS would continue operating until then. Air Force

units would be transferred from CAMS to TICARRS during FY 1996 and FY 1997. Table VII-11 presents the cost estimates for Alternative 2.

The following subsection discusses the changes to CAMS expenditures under this alternative.

a. Cost Estimate for CAMS Under Alternative 2

With this alternative, the CAMS cost estimates that were shown in Table VII-1 will be changed substantially. Table VII-12 shows the revised cost estimate for CAMS.

Unless otherwise noted, recurring CAMS costs for FY 1996 and FY 1997 are proportional to the phasing in of TICARRS during FY 1996 and FY 1997. During FY 1996, 39 percent of the sites are activated and 61 percent in FY 1997. Remaining CAMS costs are 80 and 30 percent, respectively, of FY 1994 costs.

(1) Nonrecurring Costs

CAMS Share of RPC Hardware. We assumed that if Alternative 2 is chosen, purchases of hardware for the RPCs would continue uninterrupted. The DoD is establishing Megacenters to centralize and standardize selected computer operations across DoD. Each RPC is slated to change over to a Megacenter. That portion of RPC computing capability dedicated to CAMS would become available to support Megacenter operating requirements. In FY 1998, when TICARRS is fully operational, there will be savings equivalent to the CAMS portion of RPC computer hardware. The savings were calculated as the replacement value of the equipment in the year that the change to TICARRS is completed.

Software. CSRDs would be retained for completion under Alternative 2. We assumed that further investments for enhanced editing to improve CAMS would be halted. Expenditures for system integration and test to support the continued CSRD initiatives would remain.

(2) Recurring Costs. Under Alternative 2, there would be a number of impacts on recurring costs as well. All cost elements would disappear after FY 1997. For most of the cost elements, there would be changes in the earlier years as well. These are discussed below.

Program Management. We assumed that program management costs would remain unchanged proportionally under Alternative 2 until FY 1996 and then decline through FY 1997.

Table VII-10. Cost Estimate for Alternative 1: Enhanced Version of CAMS/REMIS

	Millions of 1994 Dollars										
System	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
CAMS	67.24	51.17	50.88	47.92	46.67	46.67	46.67	52.37	46.67	46.67	502.93
REMIS	24.17	17.21	15.53	18.28	11.03	11.03	11.03	12.34	11.03	11.03	142.70
TICARRS	11.27	5.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.91
Total	102.68	74.02	66.41	66.20	57.70	57.70	57.70	64.71	57.70	57.70	662.52
Present Value	102.68	70.96	61.05	58.35	48.76	46.75	44.82	48.19	41.20	39.50	562.25

Table VII-11. Cost Estimate for Alternative 2: Enhanced Version of TICARRS

	Millions of 1994 Dollars										
System	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
CAMS	63.10	48.66	36.90	14.61	-8.30	0.00	0.00	0.00	0.00	0.00	154.98
REMIS	16.31	13.17	10.65	7.87	0.00	0.00	0.00	0.00	0.00	0.00	48.00
TICARRS	11.27	19.76	38.08	48.00	34.54	34.55	34.55	34.55	34.55	35.73	326.07
Total	90.68	81.59	86.13	70.48	26.24	34.54	34.54	34.54	34.54	35.73	529.04
Present Value	90.68	78.22	79.18	62.11	22.18	27.99	26.84	25.73	24.67	24.46	462.05

Table VII-12. Revised Cost Estimate for CAMS Under Alternative 2

		Cost in Millions of 1994 Dollars										
	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hard ware											
1.1.1	CAMS Share of RPC Hardware											
	CPUs	6.00				-8.30						-2.30
	Disks	0.45										0.45
	Silos	3.54										3.54
	Print Stations	1.80										1.80
	CAMS Share USAFE Hardware	0.25										0.25
	CAMS Share PACAF Hardware	2.00										2.00
1.2	Software											
1.2.1	Applications Software											
	Approved CRSD	1.98	1.98									3.97
	Enhanced Editing											
	System Integration and Test	0.11	0.11									0.22
	Support OT&E											
1.2.2	Data Base Initialization											
1.2.3	Documentation	0.20	0.20									0.40
1.3	Communications											
1.4	Training											
	Nonrecurring Subtotal	16.34	2.29	0.00	0.00	-8.30	0.00	0.00	0.00	0.00	0.00	10.33
2.0	Recurring Costs											
2.1	Program Management											
2.1.1	Government	0.65	0.65	0.36	0.13							1.80
2.2	Computer Operations											
2.2.1	RPC CONUS Operations											
	Direct Personnel	0.56	0.56	0.45	0.17							1.73
	Shared Personnel	4.63	4.63	3.71	1.39							14.37
	Hardware, Software, and Utilities	2.88	2.45	1.77	0.69							7.79

Table VII-12. Revised Cost Estimate for CAMS Under Alternative 2 (Continued)

		Cost in Millions of 1994 Dollars										
	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
2.2.2	RPC PACAF Operations											
	Direct	0.12	0.12	0.12	0.12							0.47
	Shared Personnel	0.65	0.65	0.65	0.65							2.62
	Hardware, Software, and Utilities	0.51	0.43	0.39	0.41							1.74
2.2.3	RPC USAFE Operations											
	Direct Personnel	0.13	0.13	0.10	0.04							0.39
	Shared Personnel	0.80	0.80	0.64	0.24							2.49
	Hardware, Software, and Utilities	0.58	0.49	0.35	0.14							1.56
2.2.4	Base Comm. Ops. CONUS											
	Civilian and Military Personnel	7.36	7.36	5.89	2.21							22.83
	Hardware, Software, and Utilities	2.16	2.16	1.73	0.65							6.70
	Base Comm. Ops. USAFE											
	Civilian and Military Personnel	1.68	1.68	1.35	0.51							5.22
	Hardware, Software, and Utilities	0.46	0.46	0.37	0.14							1.42
	Base Comm. Ops. PACAF											
	Civilian and Military Personnel	0.51	0.51	0.41	0.15							1.59
	Hardware, Software, and Utilities	0.25	0.25	0.20	0.08							0.78
2.3	User Support											
2.3.1	Field Help Group	0.61	0.61	0.49	0.18							1.90
2.3.2	Base Representatives	17.34	17.34	13.87	5.20							53.75
2.3.3	Data Base Maintenance	0.33	0.33	0.27	0.10							1.04
2.4	Communications											
2.4.1	RPC High-Speed Base Links	0.62	0.82	0.68	0.26							2.40
2.4.2	High-Speed REMIS Link											0.00
2.5	Software Maintenance											
2.5.1	Applications Software	2.50	2.50	2.00	0.75							7.77
3.5.5	System Integration and Test	0.50	0.50	0.40	0.15							1.55
2.5.2	Database Management	0.22	0.22	0.18	0.07							0.69
2.5.3	Documentation	0.28	0.28	0.22	0.08							0.86
2.6	Training and Travel	0.40	0.40	0.29	0.11							1.19
	Recurring Costs Subtotal	46.77	46.37	36.90	14.61	0.00	0.00	0.00	0.00	0.00	0.00	144.65
	Total Costs	63.10	48.66	36.90	14.61	-8.30	0.00	0.00	0.00	0.00	0.00	154.98

Operations. For both RPC operations and base communications operations, as CAMS is phased out over the FY 1995-1997 period, the cost of operating the mainframes would decrease as well. We assumed that the funding allocated to CAMS during FY 1994 and FY 1995 would remain at that level since no units would be moved from CAMS to TICARRS during that period. We assumed a decrease consistent with TICARRS activations throughout FY 1996 and FY 1997 at the RPCs in CONUS and overseas. These expenditures are identified in cost elements 2.2.1 through 2.2.6 in Table VII-1.

User Support. User support would continue until FY 1996 as planned and then declines as units/bases are converted to TICARRS.

Communications. We assumed that the high-speed (52 Kbps) lines would remain in place for the FY 1994-1995 period and then decline through FY 1996 and FY 1997 as the transition to TICARRS occurs.

High-Speed REMIS Link. This link is not required under Alternative 2.

Software Maintenance. The number of people engaged in software maintenance (including applications software, system integration and test, data base management, and documentation) at Gunter SSC, would be reduced in FY 1996 and FY 1997.

Training and Travel. Costs for FY 1996 and FY 1997 would decline as the transition to TICARRS occurs.

b. Cost Estimate for REMIS Under Alternative 2

The REMIS costs are adjusted to reflect the termination of the program in FY 1998 and reduced scope of work in FY 1996 and FY 1997 as TICARRS is activated. REMIS costs are shown in Table VII-13. Nonrecurring costs are included to complete OT&E, improve performance and REMISTALK at a reduced level of effort, update documentation, and provide training on GCSAS. This will allow the Air Force to complete the process of having REMIS replace several information systems beginning in FY 1995. The recurring costs reflect full operations of REMIS in FY 1994 and FY 1995 with support being continued at a substantial level in FY 1996 and FY 1997.

Table VII-13. Revised Cost Estimate for REMIS Under Alternative 2

	Category of Cost	Cost in Millions of 1994 Dollars										
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hardware											
1.1.1	Mainframes											
1.2	Software											
1.2.1	Application Software											
	Performance Improvement	0.93										0.93
	REMISTALK Improvement	0.13	0.13	0.13	0.13							0.52
1.2.2	Data Base Initialization	1.99	1.32									3.31
1.2.3	Documentation	0.31	0.15	0.01								0.46
1.3	Communications											
1.4	Training		0.25	0.25								0.50
1.5	Support OT&E	1.40										1.40
	Nonrecurring Subtotal	4.76	1.85	0.39	0.13	0.00	0.00	0.00	0.00	0.00	0.00	7.12
2.0	Recurring											
2.1	Program Management											
2.1.1	Government	1.26	1.10	0.87	0.62							3.85
2.1.2	Contractor	0.60	0.52	0.42	0.30							1.83
2.2	Computer Operations											
2.2.1	Central Computer											
	Operational Staff	1.47	1.47	1.47	1.47							5.88
	Hardware, Software, and Utilities	0.63	0.63	0.63	0.63							2.52
	At ALCs											
	Operational Staff											
	Hardware, Software, and Utilities	0.27	0.27	0.27	0.27							1.08
2.3	User Support	1.06	1.06	0.95	0.64							3.71
2.4	Communications	0.16	0.16	0.16	0.16							0.62
2.5	Software Maintenance											
2.5.1	Applications Software	3.97	3.97	3.57	2.38							13.89
2.5.2	Data Base Management	1.32	1.32	1.19	0.79							4.62
2.5.3	Documentation	0.26	0.26	0.24	0.16							0.93
2.6	Training and Travel	0.56	0.56	0.50	0.33							1.94
2.7	Continuity of Service											
	Recurring Subtotal	11.55	11.32	10.26	7.74	0.00	0.00	0.00	0.00	0.00	0.00	40.88
	Total	16.31	13.17	10.65	7.87	0.00	0.00	0.00	0.00	0.00	0.00	48.00

3. Comparison of Alternatives

Table VII-14 shows that the TICARRS-based alternative, Alternative 2 was estimated to have lower ten-year costs than was the alternative based on CAMS/REMIS. In present value (discounted) terms, Alternative 2 is $100 million cheaper, a savings of 18 percent relative to Alternative 1.

4. Sensitivity Analysis

In Alternative 2, a four-year transition period was assumed for TICARRS. However, there is potential for delays in both the acquisition process and in the development program. The effect on the cost of the TICARRS alternative if the program is delayed one year is reviewed in the following discussion.

To assess the costs to the TICARRS program schedule for a one-year delay, we have assumed that the contract award would be delayed for six months and the development program would take an additional six months. This has the effect of delaying the full activation of TICARRS until FY 1999. Table VIII-15 shows the impact of the one-year delay on TICARRS costs.

Using a similar methodology to that presented in Alternative 2, we estimated the costs of extending the operations of CAMS and REMIS by one year. Our revised estimates of CAMS and REMIS costs are shown in Tables VII-16 and VII-17, respectively. Table VII-18 shows our revised cost estimates for Alternative 2 with the one-year delay in fielding TICARRS.

Over the ten-year period, the present value of total costs to implement TICARRS in five years is $485.5 million, compared with $562.3 million for the CAMS/REMIS alternative (Alternative 1). This represents a savings of $76.8 million or 14 percent.

Table VII-19 presents a comparison of the costs for Alternative 1 and the revised Alternative 2.

Table VII-14. Comparison of Alternatives

Type of Cost	Millions of 1994 Dollars										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Undiscounted											
Alternative 1	102.68	74.02	66.41	66.20	57.70	57.70	57.70	64.71	57.70	57.70	662.52
Alternative 2	90.68	81.59	86.13	70.48	26.24	34.54	34.55	34.55	34.55	35.73	529.04
Discounted (Present Value)[a]											
Alternative 1	102.68	70.96	61.05	58.35	48.76	46.75	44.82	48.19	41.20	39.50	562.25
Alternative 2	90.68	78.22	79.18	62.11	22.18	27.99	26.84	25.73	24.67	24.46	462.05

[a] As recommended by Office of Management and Budget guidance, we used an annual discount rate of 4.3 percent.

Table VII-15. Revised Cost Estimate for TICARRS Under Alternative 2 With One-Year Delay in TICARRS

	Category of Cost	Cost in Millions										
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hardware											
1.1.1	Mainframes				2.46	1.97					1.06	5.49
1.2	Software											
1.2.1	Applications Software											
	Functional Enhancements		0.53	1.28								1.81
	REMIS Interfaces		0.26	0.64								0.90
	Load REMIS data				1.32							1.32
1.2.2	Data Base Initialization			3.30	6.59							9.89
1.2.3	Documentation		0.3	1.76	0.66							2.72
1.3	Communications											
1.3.1	Hardware				0.05							0.05
1.4	Training/Unit Activations											
1.4.1	Site Surveys				0.30	0.40						0.70
1.4.2	Load CAMS Data				2.43	2.43						4.85
1.4.3	User Training				1.05	1.41						2.46
1.4.4	Resolve DIREPS				1.95	2.59						4.54
1.4.5	Short-Term Support				0.53	0.70						1.23
	T&L (Site Visit)				0.06	0.07						0.13
1.4.6	T&L (Training)				0.46	0.61						1.07
1.4.7	T&L (Short-Term)				0.23	0.31						0.54
1.5	Support OT&E				2.50							2.50
	Nonrecurring Subtotal	0.00	1.10	6.97	20.58	10.49	0.00	0.00	0.00	0.00	1.06	40.20
2.0	Recurring Costs											
2.1	Program Management											
2.1.1	Government	0.71	0.77	1.31	2.51	2.17	1.42	1.42	1.42	1.42	1.42	14.57
2.1.2	Contractor	0.34	0.37	0.62	1.23	1.08	0.68	0.68	0.68	0.68	0.68	7.02
2.2	Computer Operations											
2.2.1	Central Computer											
	Computer Usage	0.50	0.50	0.50								1.50
	Operational Staff	1.68	1.68	1.68	1.80	1.95	2.22	2.22	2.22	2.22	2.22	19.88
	Hardware, Software, and Utilities	0.72	0.72	0.72	1.23	1.45	1.45	1.45	1.45	1.45	1.57	12.21

Table VII-15. Revised Cost Estimate for TICARRS Under Alternative 2 With One-Year Delay in TICARRS (Continued)

		Cost in Millions										
	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
2.2.2	Base Comm. Ops. CONUS											
	Civilian and Military Personnel				1.84	5.52	7.36	7.36	7.36	7.36	7.36	44.18
	Hardware, Software, and Utilities				0.54	1.62	2.16	2.16	2.16	2.16	2.16	12.97
2.2.3	Base Comm. Ops. USAFE											
	Cilian and Military Personnel				0.42	1.26	1.68	1.68	1.68	1.68	1.68	10.10
	Hardware, Software, and Utilities				0.22	0.34	0.46	0.46	0.46	0.46	0.46	2.85
2.2.4	Base Comm. Ops. PACAF											
	Cilian and Military Personnel				0.20	0.40	0.51	0.51	0.51	0.51	0.51	3.15
	Hardware, Software, and Utilities				0.19	0.19	0.25	0.25	0.25	0.25	0.25	1.64
2.3	User Support	2.63	2.63	2.63	4.96	6.89	7.27	7.27	7.27	7.27	7.27	56.09
2.4	Communications	0.56	0.56	0.56	1.20	1.41	1.41	1.41	1.41	1.41	1.41	11.33
2.5	Software Maintenance											
2.5.1	Application Software	2.25	2.25	2.25	2.25	2.77	2.77	2.77	2.77	2.77	2.77	25.62
2.5.2	Data Base Management	1.32	1.32	1.32	1.85	2.65	2.65	2.65	2.65	2.65	2.65	21.71
2.5.3	Documentation	0.18	0.18	0.18	0.20	0.23	0.27	0.27	0.27	0.27	0.27	2.32
2.6	Training and Travel	0.37	0.37	0.37	0.43	0.57	0.57	0.57	0.57	0.57	0.57	4.97
2.7	Continuity of Service				0.18	0.18	0.18	0.18	0.18	0.18	0.18	1.26
	Recurring Subtotal	11.27	11.35	12.15	21.25	30.67	33.31	33.31	33.31	33.31	33.43	253.38
	Total	11.27	12.45	19.12	41.83	41.17	33.31	33.31	33.31	33.31	34.49	293.58

Table VII-16. Revised Cost Estimate for CAMS Under Alternative 2 With One-Year Delay in TICARRS

		Cost in Millions										
	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hard ware											
1.1.1	CAMS Share of RPC Hardware											
	CPUs	6.00					-6.64					-0.64
	Disks	0.45										0.45
	Silos	3.54										3.54
	Print Stations	1.80										1.80
	CAMS Share of USAFE Hardware	0.25										0.25
	CAMS Share of PACAF Hardware	2.00										2.00
1.2	Software											
1.2.1	Application Software											
	Approved CRSD	1.32	1.32	1.32								3.97
	Enhanced Editing											0.00
	System Integration and Test	0.11	0.11	0.11								0.34
	Support OT&E											
1.2.2	Data Base Initialization											
1.2.3	Documentation	0.13	0.13	0.13								0.40
1.3	Communications											
1.4	Training											
	Nonrecurring Subtotal	15.61	1.57	1.57	0.00	0.00	-6.64	0.00	0.00	0.00	0.00	12.10
2.0	Recurring Costs											
2.1	Program Management											
2.1.1	Government	0.59	0.59	0.59	0.50	0.13						2.40
2.2	Computer Operations											
2.2.1	RPC CONUS Operations											0.00
	Direct Personnel	0.56	0.56	0.56	0.45	0.17						2.29
	Shared Personnel	4.63	4.63	4.63	3.71	1.39						19.00
	Hardware, Software, and Utilities	2.88	2.88	2.45	1.77	0.69						10 67
2.2.2	RPC PACAF Operations											0.00
	Direct Personnel	0.'2	0.12	0.12	0.12	0.12						0.59
	Shared Personnel	0.65	0.65	0.65	0.65	0.65						3.27
	Hardware, Software, and Utilities	0.51	0.51	0.43	0.39	0.41						2.25

Table VII-16. Revised Cost Estimate for CAMS Under Alternative 2 With One-Year Delay in TICARRS (Continued)

		Cost in Millions										
	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
2.2.3	RPC USAFE Operations											0.00
	Direct Personnel	0.13	0.13	0.13	0.10	0.04						0.52
	Shared Personnel	0.80	0.80	0.80	0.64	0.24						3.29
	Hardware, Software, and Utilities	0.58	0.58	0.49	0.35	0.14						2.13
2.2.4	Base Comm. Ops. CONUS											0.00
	Civilian and Military Personnel	7.36	7.36	7.36	5.89	2.21						30.19
	Hardware, Software, and Utilities	2.16	2.16	2.16	1.73	0.65						8.86
2.2.5	Base Comm. Ops. USAFE											0.00
	Civilian and Military Personnel	1.68	1.68	1.68	1.35	0.51						6.91
	Hardware, Software, and Utilities	0.46	0.46	0.46	0.37	0.14						1.88
2.2.6	Base Comm. Ops. PACAF											0.00
	Civilian and Military Personnel	0.51	0.51	0.51	0.41	0.15						2.10
	Hardware, Software, and Utilities	0.25	0.25	0.25	0.20	0.08						1.04
2.3	User Support											0.00
2.3.1	Field Help Group	0.61	0.61	0.61	0.49	0.18						2.51
2.3.2	Base Representatives	17.34	17.34	17.34	13.87	5.20						71.09
2.3.3	Data Base Maintenance	0.33	0.33	0.33	0.27	0.10						1.37
2.4	Communications											0.00
2.4.1	RPC High-Speed Base Links	0.62	0.62	0.82	0.68	0.26						3.02
2.4.2	High-Speed REMIS Link											0.00
2.5	Software Maintenance											0.00
2.5.1	Applications Software	2.50	2.50	2.50	2.00	0.75						10.27
3.5.5	System Integration and Test	0.50	0.50	0.50	0.40	0.15						2.05
2.5.2	Data Base Management	0.22	0.22	0.22	0.18	0.07						0.91
2.5.3	Documentation	0.28	0.28	0.28	0.22	0.08						1.14
2.6	Training and Travel	0.38	0.38	0.38	0.31	0.11						1.57
	Recurring Subtotal	46.69	46.69	46.29	37.07	14.61	0.00	0.00	0.00	0.00	0.00	191.35
	Total Costs	62.30	48.25	47.86	37.07	14.61	-6.64	0.00	0.00	0.00	0.00	203.45
	Total Discounted Costs	59.73	44.36	42.18	32.65	11.84	0.00	0.00	0.00	0.00	0.00	190.75

Table VII-17. Revised Cost Estimate for REMIS With One-Year Delay in TICARRS

		Cost in Millions										
	Category of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
1.0	Nonrecurring Costs											
1.1	Hardware											
1.1.1	Mainframes											
1.2	Software											
1.2.1	Applications Software											
	Performance Improvement	0.93										0.93
	REMISTALK Improvement	0.13	0.13	0.13	0.13	0.13						0.65
1.2.2	Initialize Data Base	1.99	1.32									3.31
1.2.3	Documentation	0.31	0.15	0.01	0.01	0.01						0.48
1.3	Communications											0.00
1.4	Training		0.25	0.25								0.50
1.5	Support OT&E	1.40										1.40
1.6	Security											
	Nonrecurring Subtotal	4.76	1.85	0.39	0.14	0.14	0.00	0.00	0.00	0.00	0.00	7.27
2.0	Recurring Costs											
2.1	Program Management											
2.1.1	Government	1.26	1.26	1.10	0.87	0.62						5.11
2.1.2	Contractor	0.60	0.60	0.52	0.42	0.30						2.43
2.2	Computer Operations											
2.2.1	Central Computer											
	Operational Staff	1.47	1.47	1.47	1.47	1.47						7.35
	Hardware, Software, and Utilities	0.63	0.63	0.63	0.63	0.63						3.15
2.2.2	ALCs											
	Operational Staff											
	Hardware, Software, and Utilities	0.27	0.27	0.27	0.27	0.27						1.35
2.3	User Support	1.06	1.06	1.06	0.95	0.64						4.77
2.4	Communications	0.16	0.16	0.16	0.16	0.16						0.78
2.5	Software Maintenance											
2.5.1	Applications Software	3.97	3.97	3.97	3.57	2.38						17.86
2.5.2	Data Base Management	1.32	1.32	1.32	1.19	0.79						5.94
2.5.3	Documentation	0.26	0.26	0.26	0.24	0.16						1.19
2.6	Training and Travel	0.56	0.56	0.56	0.50	0.33						2.50
2.7	Continuity of Service											
	Recurring Subtotal	11.55	11.55	11.32	10.26	7.74	0.00	0.00	0.00	0.00	0.00	52.43
	Total	16.31	13.40	11.71	10.40	7.88	0.00	0.00	0.00	0.00	0.00	59.71

Table VII-18. Cost Estimates for Alternative 2 With One-Year Delay in TICARRS

	Millions of 1994 Dollars										
System	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
CAMS	62.30	48.25	47.86	37.07	14.61	-6.64					203.45
REMIS	16.31	13.40	11.71	10.40	7.88						59.71
TICARRS	11.27	12.45	19.12	41.83	41.17	33.31	33.31	33.31	33.31	34.49	293.58
Total	89.87	74.10	78.69	89.30	63.66	26.67	33.31	33.31	33.31	34.49	556.73
Present Value	89.87	71.05	72.33	78.70	53.80	21.61	25.88	24.81	23.79	23.62	485.45

Table VII-19. Comparison of Alternatives With One-Year Delay in TICARRS

	Millions of 1994 Dollars										
Type of Cost	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Undiscounted											
Alternative 1	102.68	74.02	66.41	66.20	57.70	57.70	57.70	64.71	57.70	57.70	662.52
Alternative 2	89.87	74.10	78.69	89.30	63.66	26.67	33.31	33.31	33.31	34.49	556.73
Discounted (Present Value)[a]											
Alternative 1	102.68	70.96	61.05	58.35	48.76	46.75	44.82	48.19	41.20	39.50	562.25
Alternative 2	89.87	71.05	72.33	78.70	53.80	21.61	25.85	24.81	23.79	23.62	485.45

[a] As recommended by Office of Management and Budget guidance, we used an annual discount rate of 4.3 percent.

VIII. CONCLUSIONS

This paper describes IDA's comparison of the effectiveness and costs of two alternative Air Force maintenance information systems, CAMS/REMIS and TICARRS. Two formal alternatives were defined and reviewed in detail. We evaluated CAMS/REMIS and TICARRS as they exist today (considering current plans and available budgets). CAMS/REMIS is the standard Air Force maintenance information system. TICARRS is used to provide broad direct support to the F-16 and F-117 communities and serves many weapon system management functions for the F-15 and F-16.

We compared the systems along six dimensions of effectiveness: system functionality (what they do), scope (for what systems and equipment), operating characteristics (their availability, responsiveness, and ease of use), data accuracy and completeness, adaptability (their ability to respond quickly to changes in user needs and to ease the transition to the next generation maintenance information system), and logistics and operational effectiveness (measured by mean time between failures, maintenance man-hours per flying hour and mission-capable rates). Limitations of the systems were identified through a review of available documentation and extensive discussions with users and system developers. In addition, IDA was able to use the Operational Assessment of TICARRS that took place at Seymour Johnson AFB during the spring of 1993 to better understand some of its particular strengths and shortcomings. Because there were relatively few REMIS users and REMIS has not yet achieved its full operating capability, we conducted a special test of its functionality and selected operating characteristics. To the extent possible, steps required to overcome the limitations of each system were specified and cost estimates developed.

The ten-year costs of the systems, modified as needed to improve their effectiveness, were then compared. A ten-year time period was used because it seems likely that newer information system technology should displace whatever system is chosen in about ten years.

The remainder of this chapter summarizes the major findings of our work.

A. EVALUATION OF EXISTING SYSTEMS

Table VIII-1 summarizes IDA's findings regarding the effectiveness of CAMS/REMIS and TICARRS as they exist today.

Table VIII-1. Comparison of the Effectiveness of CAMS/REMIS and TICARRS

Dimension of Effectiveness	Conclusion
Functionality	Greater for CAMS/REMIS
Scope	Greater for CAMS/REMIS
Operating characteristics	
Availability	Better for TICARRS
Responsiveness	Better for TICARRS
Ease of use	Equal at wing level, TICARRS better elsewhere
Data accuracy and completeness	Better for TICARRS
Adaptability	TICARRS better in short-term; little long-term difference
Logistics and operational effectiveness	No difference found

1. Functionality

Today, CAMS/REMIS has greater functionality, although there are some functions for which TICARRS is unique (e.g., block number tracking). Among other things, CAMS provides interfaces with the Standard Base Supply System and the Comprehensive Engine Management System, and handles personnel and training management. Gaps in the functionality of TICARRS were identified during the Operational Assessment at Seymour Johnson AFB. Relatively Conclusionsg the Operational Assessment. Important ones that were not eliminated included: production scheduling and management (provision of maintenance snapshots), appropriate handling of PQDRs, and the means to provide a 14-day records check in an Air Force-approved manner.

2. Scope

CAMS/REMIS currently supports far more aircraft and other products (communications-electronics equipment, AGE, etc.) than does TICARRS. If TICARRS were to replace CAMS/REMIS, it would have to be modified to address more than 40 additional aircraft types and 1,700 types of communications and electronic equipment.

3. Operating Characteristics

Overall, TICARRS has substantially better operating characteristics than does CAMS/REMIS. These are briefly described in the following paragraphs.

a. Availability

Regarding system performance parameters, TICARRS and REMIS provide very high levels of availability when compared to CAMS. TICARRS and REMIS both have had less than one percent of unscheduled downtime. CAMS has been unable to approach its target of 95 percent availability at the vast majority of bases.

b. Responsiveness

TICARRS has better response time, particularly compared to REMIS. Some evidence indicated that TICARRS was able to produce standard reports in less than 30 minutes, while REMIS averaged 2.4 hours. Ad hoc REMIS reports took an average of 7.5 hours and in some cases up to 36 hours.

c. Ease of Use

Regarding ease of use, neither system is convincingly superior at the wing level. Discussions with a wide range of wing-level users uncovered more enthusiasm for TICARRS than for CAMS, but surveys conducted during the Operational Assessment at Seymour Johnson AFB judged the two systems roughly equal.[1] Other users (depots, MAJCOM, weapon system SPOs, and contractors) emphasized problems with REMIS—with significant exceptions at the depot level—and exhibited a preference for TICARRS when they were familiar with it.

4. Data Accuracy and Completeness

Where comparisons are possible, TICARRS has been shown to have more complete and accurate data. Over a quarter of avionics parts arriving for depot-level repair have not had a maintenance action appropriately recorded in CAMS. An examination of serially-controlled parts on F-16 aircraft undergoing phase inspections found that between 20 and 40 percent of the changes made between periodic inspections were not recorded in CAMS. This compares with a level of 6 percent in TICARRS when it was supporting F-16 maintenance at the wing level.

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1 After four weeks, users exhibited a clear preference for TICARRS. At six weeks, more satisfaction was expressed for CAMS. Throughout the assessment, a substantial percentage of users were indifferent to the information system. The fact that the Operational Assessment was limited to six weeks must be considered in attempting to assess the ease of use of TICARRS. A longer performance period may result in very different opinions.

REMIS has experienced wide-spread, persistent failure to receive the data it is supposed to get from CAMS. A study comparing LRU removals in REMIS and TICARRS found no data from the REMIS standard query and only minimal data in REMISTALK. Only the TICARRS data seemed realistic.

REMIS has been rejecting between 8 and 11 percent of the aircraft-related information (which represents one of the most critical types of equipment tracked in REMIS) it receives from CAMS because of data errors. For all equipment types, the total reject rate has ranged between 16 and 21 percent.[2]

5. Adaptability

TICARRS is more adaptable in some ways. The Operational Assessment at Seymour Johnson showed that minor modifications to the system could be made quickly. TICARRS appears to be closer than CAMS to being able to deploy the kind of stand-alone system needed for wartime.

Neither system is likely to have a distinct advantage in aiding the transition to the next generation of maintenance information systems.

6. Logistics and Operational Effectiveness

We found no statistically significant relationships between the choice of maintenance information system and indicators of aircraft readiness and supportability (mission-capable rate, mean time between failures, and maintenance man-hours per flying hour). This is a short-run result, and does not address the issue of using the information from these systems in longer-term efforts to identify bad actors, justify modifications, and so on.

7. Summary

CAMS/REMIS now handles a greater number of weapon systems and other types of equipment than does TICARRS. It also has several important functions that are missing from TICARRS. However, TICARRS operates better, and has the inherent capability to provide more accurate and complete data.

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2 This may reflect problems with CAMS data, not REMIS's ability to produce valid edit checks.

B. THE ABILITY OF THE SYSTEMS TO OVERCOME THEIR SHORTCOMINGS

In deciding which maintenance information system could best fill the Air Force's requirements over the next ten years, one must consider the ability of the systems to overcome their shortcomings.

A project is under way to improve some of CAMS's operating characteristics. The fielding of REMIS's GCSAS subsystem holds the promise of improving the accuracy of CAMS (and thus REMIS) data. REMIS is addressing some of its responsiveness problems. Our cost estimates include some additional expenditures to further improve these characteristics.

Given the amounts of money dedicated to improving the performance of each system, it is appropriate to assess the technical risk involved in successfully completing the required system improvements.

In our judgment, overall risk is low to medium for the CAMS/REMIS alternative and low for the TICARRS alternative.

There are some aspects of the design and history of CAMS/REMIS that cast doubt on the ability of that system to significantly improve its performance.

The move to Regional Processing Centers will not, by itself, improve the availability of CAMS. Improvements to availability are dependent upon: (1) improved software quality and (2) the provision of the appropriate mix of skilled personnel (data base managers) at the bases. Moreover, CAMS will continue to be operated in an environment in which it must compete with other base-level applications for computer system resources. System responsiveness is likely to continue to suffer in the future.

It should be possible to adequately improve the responsiveness of REMIS. We believe that this will require substantially greater resources than are currently being applied.

The biggest potential problem involves the completeness and accuracy of CAMS and REMIS data. The fielding of GCSAS may improve the situation, but the complex nature of the interface between the two systems, and the data rejects that may still result, could result in data that are not accurate enough to meet some of the Air Force's requirements. It is difficult enough to enforce data integrity within one system. CAMS/REMIS may be programmatically one system but they are, in reality, two systems, with different record formats and different edits.

While it appears that TICARRS is capable of being expanded in functionality and scope to perform the tasks that CAMS/REMIS currently supports, a major expansion is not without risks. In our analysis of alternative systems, we included the cost of expanding TICARRS and changing all Air Force units from CAMS to TICARRS, estimated to be over $40 million. Even though limitations in scope and functionality are weaknesses of TICARRS today, the flexibility of the system's architecture supports optimism about TICARRS's ability to be expanded as needed.

C. COSTS

1. Alternative 1: Enhanced Version of CAMS/REMIS

We estimated that the alternative based on CAMS/REMIS would cost $663 million (in FY 94 dollars) over the next ten years ($562 million when future costs are discounted). The major cost drivers are user support at the bases and computer operations.[3] Historically, CAMS has operated with an average of three to four data base managers per base, and we see no factors that would significantly change that level in the future. We have not attributed any costs related to computer equipment that has already been purchased for the RPCs to CAMS.

2. Alternative 2: Enhanced Version of TICARRS

We assumed that the functionality of TICARRS can be expanded to match that of CAMS/REMIS by the end of FY 1995. Adding the required functionality is not, in our judgment, a major cost driver. The major cost drivers associated with expanding TICARRS are in:

- initializing the data base for each new weapon system,
- acquiring additional hardware to handle the additional work load, and
- changing the individual Air Force units from CAMS to TICARRS.

Moreover, the various requirements of a formal MAISRC acquisition process result in TICARRS being fielded in place of CAMS/REMIS no earlier than FY 1997. An alternative based on TICARRS was estimated to have a ten-year cost of $529 million ($462 million when discounted).

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3 The CAMS architecture is inherently expensive because it is replicated at all bases, even with the advent of the RPCs. We considered only the CAMS portion of the computer costs as relevant to our analysis. It is worth noting that CAMS's costs would be even higher without the RPCs.

D. OVERALL CONCLUSIONS

In our judgment, an alternative based on implementation of TICARRS provides at least as great effectiveness with less risk and less cost than CAMS/REMIS. In terms of effectiveness, CAMS/REMIS now suffers from problems with availability, responsiveness, and data integrity. TICARRS is currently missing some important elements of functionality and cannot support as many systems and kinds of equipment as can CAMS/REMIS. In our cost analysis, we included the cost of additional work needed to overcome the shortcomings of both systems. This included work to improve CAMS editing capability, including real-time access from CAMS to REMIS for fleet-wide information. We remain very uncertain, however, that the data integrity problems of CAMS/REMIS can be fully overcome. Not only have these problems been persistent, but the CAMS/REMIS architecture works against their simple resolution.

We conclude that when all the relevant costs are considered, a system based on TICARRS would be more cost-effective than one based on CAMS/REMIS.

Assuming a four-year phase-in period, we estimated that the Air Force could save $100 million in present value terms over the next ten years by choosing a TICARRS-based system. This is 18 percent of what we estimated it would cost to operate a CAMS/REMIS-based system over that period. If the policies and procedures of the acquisition process require longer to change over to a TICARRS-based system (i.e., five years), we estimated that the Air Force could save $77 million in present value terms over the ten-year period.

APPENDIX A

BAD ACTORS AND DATA ACCURACY

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BAD ACTORS AND DATA ACCURACY

Data accuracy and completeness was one of our seven dimensions of effectiveness. We discovered that the degree of accuracy needed varied depending on the application. To illustrate the consequences of data accuracy in one application, we investigated the relationship between the detection of a bad actor and data accuracy.

The detection of a bad actor depends upon the accuracy and completeness of the data system being used to track line replaceable units (LRUs). This dependency will be illustrated by computing the expected number of maintenance cycles that an LRU is in the maintenance system before it is detected and classified as a bad actor, given a specific level of data system accuracy. A maintenance cycle is defined as the time a part is tested and fails to the time it is tested and fails again.

A study on the relationship between data accuracy and the detection of bad actors was done by Dynamics Research Corporation.[1] A Markov chain approach was used. We examined that analysis and made some modifications. We also used a Markov chain approach to determine the relationship between the detection of a bad actor and data system accuracy and completeness. The analysis focused on a particular LRU's life cycle, independent of its delivery to the Air Force. The process begins with a set of operating aircraft with a set of spares (of which some may be bad actors). We made the following assumptions:

- A bad actor is defined as any LRU that has experienced three or more bench check serviceable (BCS) actions within a 90-day period. To declare a part a bad actor, three BCSs need to have been recorded in the data system within a 90-day period.
- The Air Force data system started with no a priori knowledge of the state of the part.
- A maintenance cycle is 30 days long.

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1 Allan Kleinman, "The Impact of Data System Accuracy on Detecting Bad Actors," Dynamics Research Corporation.

- Every 30 days, a BCS takes place, along with an opportunity to record the observation in the data system. The observation may or may not be recorded, and even if recorded, the possibility of error exists;
- A failure occurred at time $t = 0$ and the opportunity to record the observation is instantaneous.

Thus, it is possible to detect a bad actor (three or more recorded BCSs within a 90-day period) within a 60-day period. It is also possible to have three recorded BCSs with one inaccurate or missed record between them, within a 90-day period. Hence, the model needs to include a 90-day "window" over the opportunities to record the BCS. Note that the possibility of misidentifying a part as a bad actor was not included in this analysis. Further investigation would have needed to be done.

The process can be modeled as a Markov chain. A Markov chain is a stochastic process that takes on a finite or countable number of possible values or states and exhibits the Markovian property (i.e., the probability of the process moving to a future state depends only on the present state and not on past states). Also, the probability of moving from state to state is not dependent on time. The states of the process for the first case we examined are shown in Figure A-1.

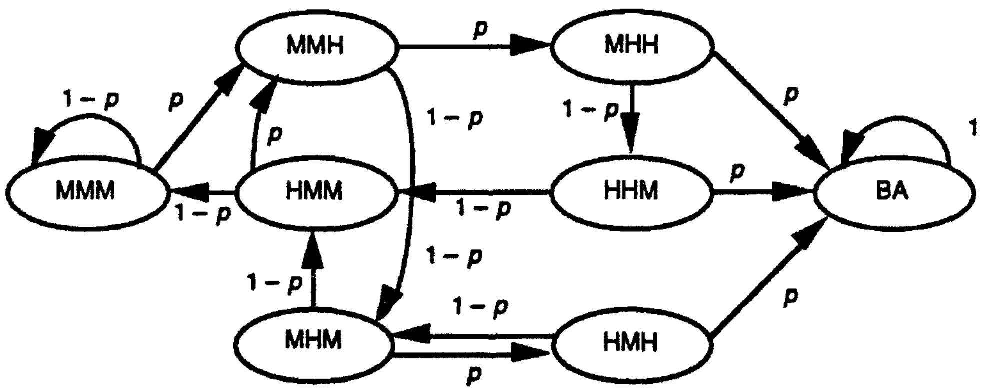

Figure A-1. Markov Chain State Diagram: Case 1

The states of the Markov chain are labeled with letters to represent the results of the last three opportunities to record bench check serviceables, where the third letter represents the result of the most recent observation that has occurred, the second letter represents the the result of the second most recent, and the first letter represents the third most recent. The results fall into two classes: (1) the data was accurately recorded, denoted as H ("Hit"), or (2) any other possibility (not recorded, recorded inaccurately, etc.), denoted as M ("Miss"). For example, the state MHH represents two observations accurately recorded in the data

system in the last two maintenance cycles and one "missing" observation in the data system three maintenance cycles ago. So, if during the next maintenance cycle the BCS was accurately recorded, the part would be declared a bad actor because there are three recorded BCSs within a 90-day period. The state BA ("Bad Actor") represents the detection and elimination of a bad actor (an absorbing state). By defining the states in such a way, we have implicitly included a 90-day "window" in the model. The chain moves from state to state with probability p (data system accuracy) or $1 - p$ (error rate).

Given this model, we can determine the expected number of maintenance cycles that a bad actor remains in the maintenance system before it is detected and eliminated. To do so, we constructed a one-step transition matrix (shown in Table A-1) based on Figure A-1. This matrix contains one-step transition probabilities P_{ij}, which represent the probability that the process will, when in state i, make a transition into state j.

Table A-1. Matrix of One-Step Transition Probabilities P_{ij} (where $q = 1 - p$)

	MMM	MMH	MHM	HMM	MHH	HHM	HMH	BA
MMM	q	p	0	0	0	0	0	0
MMH	0	0	q	0	p	0	0	0
MHM	0	0	0	q	0	0	p	0
HMM	q	p	0	0	0	0	0	0
MHH	0	0	0	0	0	q	0	p
HHM	0	0	0	q	0	0	0	p
HMH	0	0	q	0	0	0	0	p
BA	0	0	0	0	0	0	0	1

Let X<*i*> be the state vector for which each of its elements correspond to the probability of being in a given state at time *i*. Let X<0> represent the initial condition of the system where no observations have been made, that is, X<0> = [1, 0, 0, 0, 0, 0, 0, 0]. Thus, the chain starts in state MMM.

To determine the state probability vectors for, say, i = 1, ..., 8, the following equation is used: X<*i*> = X<*i* – 1> * *P*. An interesting result obtained from this series of equations is the probability of detecting and eliminating a bad actor by time *i*. The last element of the state vector X<*i*> represents this probability, which we will denote as XBA<*i*>. Figure A-2 illustrates the probability that a bad actor has been detected and eliminated by time *i* for a data accuracy of 90 percent.

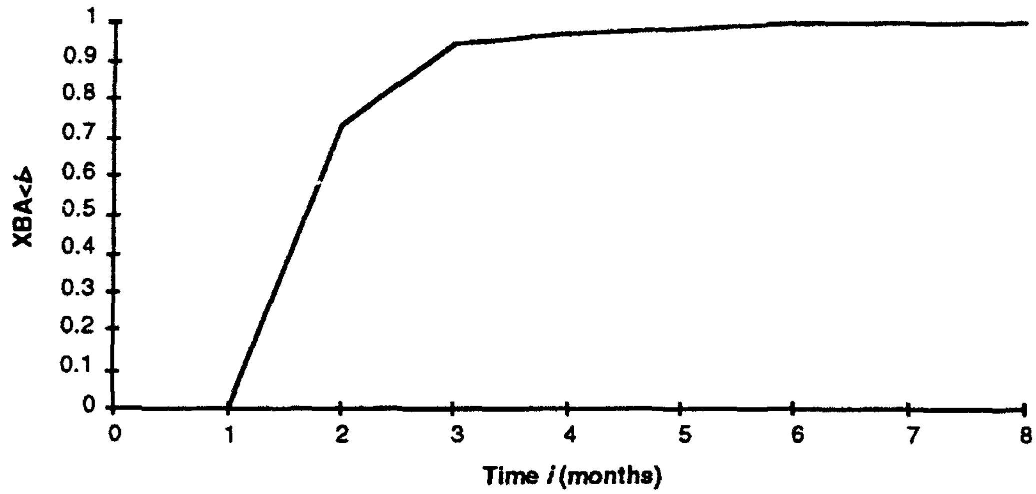

Figure A-2. Cumulative Probability of Detecting and Eliminating a Bad Actor by Time *i* Given a Data Accuracy of 90 Percent

The next step is to determine the probability distribution for detecting a bad actor at time i. We can compute this distribution from the above cumulative probabilities. The probability of detection at time i is the difference between the cumulative probability that a part is declared a bad actor at time i and the cumulative probability that it was declared a bad actor at time $(i - 1)$. The distribution is shown in Figure A-3.

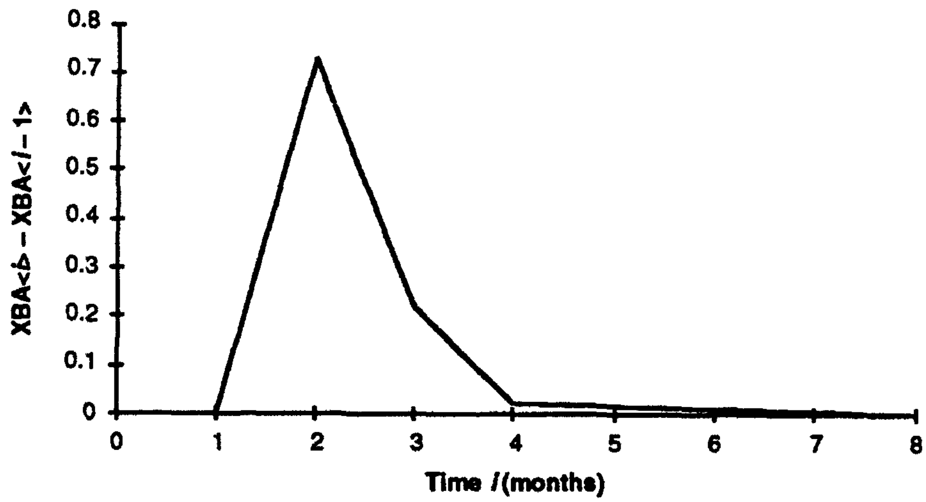

Figure A-3. Probability of Detecting a Bad Actor at Time *i* Given a Data Accuracy of 90 Percent

The expected number of months that a bad actor is in the system is:

$\sum i * (XBA\langle i\rangle - XBA\langle i - 1\rangle) = 2.377$ ($i = 1, \ldots, 100$) for a data accuracy of 90 percent.

This includes the assumption that the first step of the Markov chain was instantaneous (both a failure and the opportunity to record the failure occurred at $t = 0$). Figure A-4 and Table A-2 represent the expected time to detect bad actors for a range of data system accuracies.

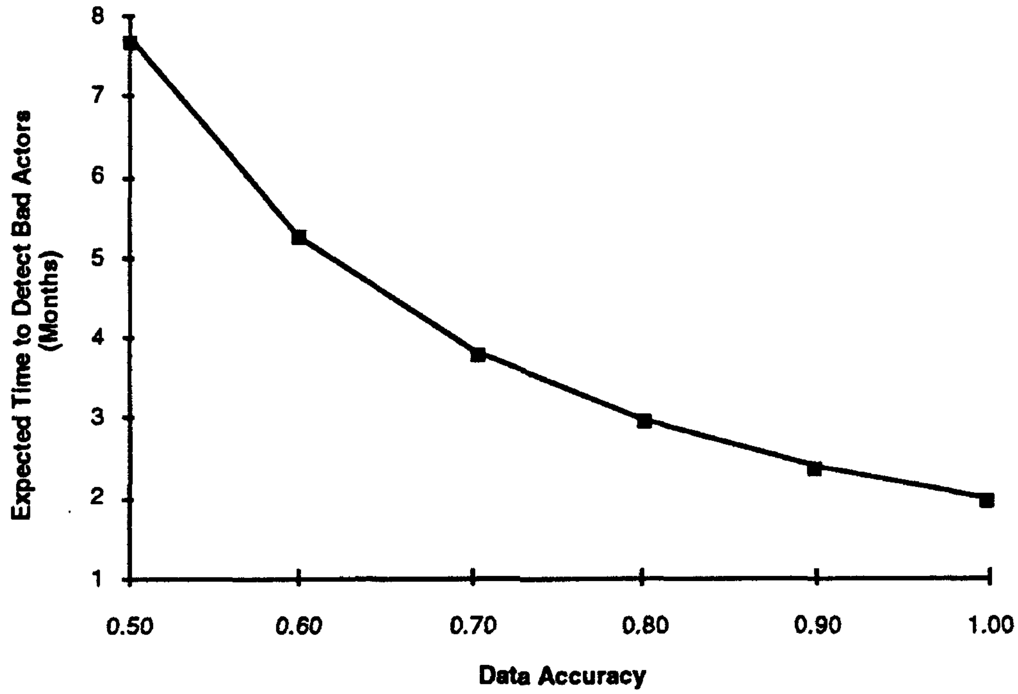

Figure A-4. Expected Lifetime of a Bad Actor versus Data System Accuracy

Table A-2. Expected Lifetime of a Bad Actor Given Levels of Data Accuracy

Data Accuracy	Expected Lifetime of Bad Actor (months)
.50	7.769
.60	5.271
.70	3.841
.75	3.348
.80	2.953
.90	2.377
.98	2.063
.99	2.031

Thus, for a 90-percent accurate data system, a bad actor should be detected, on the average, in less than 2.5 months.

A second case was investigated. For this case, an additional assumption was made: At the time of the third failure (within a 90-day period), the maintenance crew will first check the data system to see the past history of the part and, if two failures are found, then accurately record the third BCS and declare the part a bad actor. Thus, the probability of accurately recording the third BCS that has occurred within a 90-day period is one. In the first case, there was a positive probability that this third occurrence may not be recorded accurately or at all. Also, the maintenance crew was not responsible for declaring a part a bad actor.

Figure A-5 below shows the Markov chain state transition diagram for the second case.

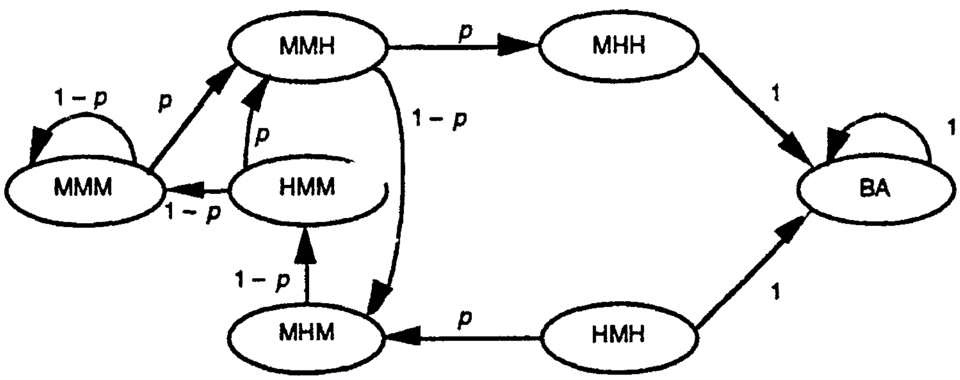

Figure A-5. Markov Chain State Diagram: Case 2

The same analysis previously described was done based on the above diagram. The following graphs represent the pertinent results. Figure A-6 represents the probability that a bad actor will be detected and eliminated by time *i* for a data accuracy of 90 percent.

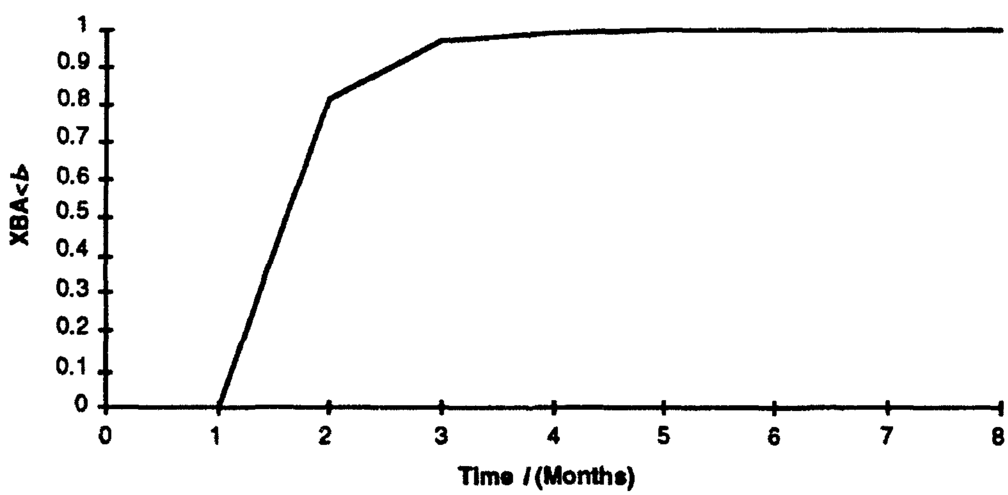

Figure A-6. Cumulative Probability of Detecting and Eliminating a Bad Actor by Time *i* Given a Data Accuracy of 90 Percent

Figure A-7 represents the probability that a bad actor was detected at time *i*.

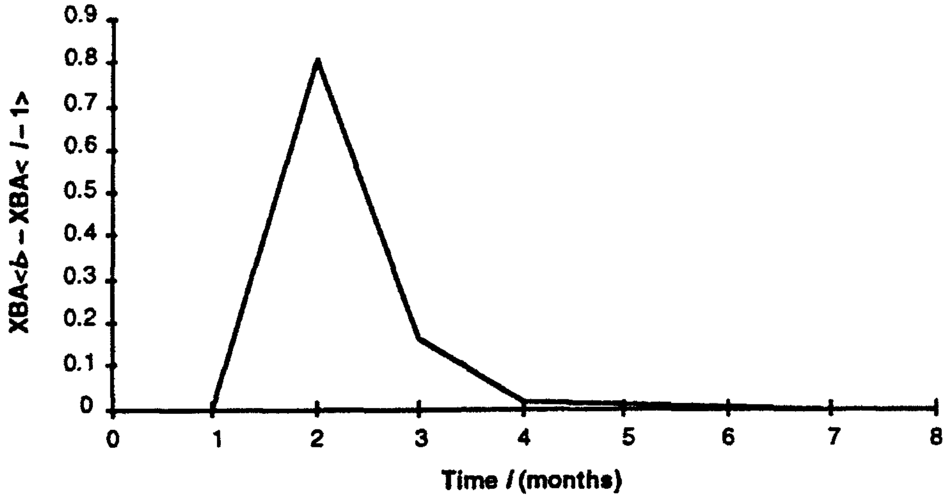

Figure A-7. Probability of Detecting a Bad Actor at Time *i* Given a Data Accuracy of 90 Percent

Figure A-8 and Table A-3 represent the average amount of time to detect a bad actor for various data accuracies.

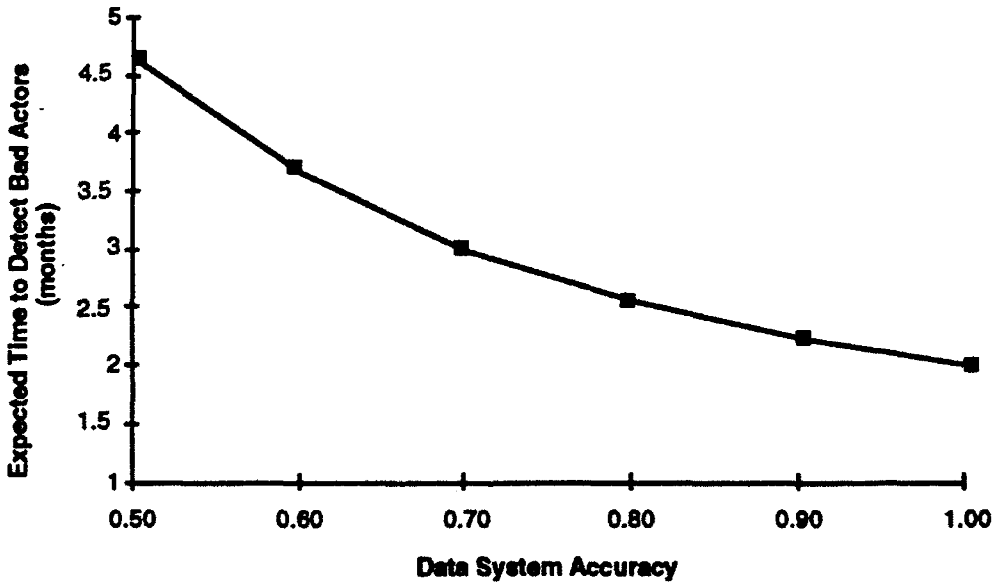

Figure A-8. Expected Lifetime of Bad Actors versus Data System Accuracy

Table A-3. Expected Lifetime of A Bad Actor Given Levels of Data Accuracy

Data Accuracy	Expected Lifetime (Months)
.50	4.667
.60	3.651
.70	2.998
.75	2.756
.80	2.552
.90	2.233
.98	2.041
.99	2.020

Thus, for a system with 90 percent accuracy, a bad actor should be detected, on the average, in approximately 2.2 months. Comparing the two cases that were considered, one can see that for lower levels of data accuracy, the average amount of time to detect a bad actor was much higher in the first case than in the second case. As data accuracy increases, the time needed to detect a bad actor decreases at a faster rate in the first case. For higher levels of data accuracy, the amount of time to detect a bad actor approaches 2 months in both cases. For data accuracy of 100 percent, a bad actor can be detected in 2 months.

Overall, this analysis shows that as levels of data accuracy increase, the amount of time to detect a bad actor decreases. It also provides some insight on the range of data accuracy that would be sufficient for identifying a bad actor. However, the costs associated with various levels of accuracy should also be a factor in determining the range of data accuracy.

APPENDIX B

LITERATURE REVIEW

I. Information Systems

A. CAMS

1 CAMS AF Manual 66-279, User's Manual, Vol. I, 11/1/90
2 CAMS AF Manual 66-279, User's Manual, Vol. II, 12/1/90
3 CAMS AF Manual 66-279, User's Manual, Vol. III, 11/1/92
4 CAMS AF Manual 66-279, User's Manual, Vol. IV, 6/1/91
5 CAMS AF Manual 66-279, User's Manual, Vol. V, 3/1/91
6 CAMS AF Manual 66-279, User's Manual, Vol. VI, 1/1/93
7 CAMS AF Manual 66-279, User's Manual, Vol. VII, 11/1/92
8 CAMS AF Manual 66-279, User's Manual, Vol. VIII, 2/1/93
9 CAMS AF Manual 66-279, User's Manual, Vol. IX, 1/15/93
10 CAMS AF Manual 66-279, User's Manual, Vol. X, 11/1/89
11 CAMS AF Manual 66-279, User's Manual, Vol. XI, 8/1/92
12 CAMS AF Manual 66-279, User's Manual, Vol. XII, 8/1/92
13 CAMS AF Manual 66-279, User's Manual, Vol. XIII, 2/1/93
14 CAMS AF Manual 66-279, User's Manual, Vol. XIV, 6/1/91
15 CAMS AF Manual 66-279, User's Manual, Vol. XV, 3/1/92
16 CAMS AF Manual 66-279, User's Manual, Vol. XVI, 2/1/93
17 CAMS AF Manual 66-279, User's Manual, Vol. XVII, 3/1/92
18 CAMS AF Manual 66-279, User's Manual, Vol. XVIII, 2/1/90
19 CAMS AF Manual 66-279, User's Manual, Vol. XIX, 3/1/92
20 CAMS AF Manual 66-279, User's Manual, Vol. XX, 11/1/92
21 CAMS AF Manual 66-279, User's Manual, Vol. XXI, 2/1/93
22 CAMS AF Manual 66-279, User's Manual, Vol. XXII, 11/1/89
23 CAMS AF Manual 66-279, User's Manual, Vol. XXIV, 9/1/90
24 CAMS AF Manual 66-279, User's Manual, Vol. XXV, 2/1/93
25 CAMS AF Manual 66-279, User's Manual, Vol. XXVI, 9/1/92
26 CAMS AF Manual 66-279, User's Manual, Vol. XXVII, 3/1/92
27 CAMS Computer Operation Manual, Vol. I, 3/1/92
28 CAMS Implementation Procedures, Vol. XI, 3/1/92
29 CAMS Functional Description: Basic, 5/12/83
30 CAMS Functional Description: Supplement 1, 5/12/83
31 CAMS Functional Description: Supplemen 1B, 5/1/84
32 CAMS Functional Description: Supplement 2, 5/12/83
33 CAMS Functional Description: Supplement 3, 5/12/83
34 CAMS Functional Description: Supplement 3B, 6/87
35 CAMS Functional Description: Supplement 4, 5/12/83
36 CAMS Functional Description: Supplement 5, 5/1/84
37 CAMS Functional Description: Supplement 6, 6/1/92
38 CAMS Functional Description: Supplement 7, 5/12/83
39 CAMS Functional Description: Supplement 8, 5/18/84
40 CAMS Communications-Computer Systems Program Plan, Telecommunications Support Plan, Draft, 9/1/92
41 CAMS Communications-Computer Systems Program Plan, Security Support Plan, Draft, 9/1/92
42 CAMS Communications-Computer System Support Plan, 12/1/92
43 CAMS Security Risk Analysis by Data Systems Design Office, Maintenance Systems Division, Gunter AFS, 11/20/84

B. REMIS

1 REMIS TEMP, 6/19/92
2 Draft REMIS TEMP

3 AFLC 001-92, Operational Requirements Document for REMIS, 4/28/92
Attachments:
REMIS Critical Systems Characteristics/Requirements Correlation Matrix
Security Support Plan
Logistics Support Plan
Configuration Management Support Plan
Concept of Engineering
AFLC Command Dictionary Directory
REMIS Master Schedule and Program Schedule
4 Draft AFLC 001-92, Operational Requirements Document for REMIS, 10/91
5 Communications Management Support Plan, 7/15/92
6 REMIS Architectural Analysis by Logistic Systems Architects, 3/8/90
7 Computer Program Timing and Sizing Data for REMIS, prepared by Litton Computer Services, 8/31/88
8 Functional Description for REMIS, 10/24/89
9 REMIS ADHOC with REMIS TALK by Litton Computer Services
10 EIMSURS: Equipment Inventory, Multiple Status, Utilization Reporting Subsystem

C. CAMS and REMIS

1 Concept of Operations (CONOPS) for CAMS/REMIS, 12/17/92
2 CAMS/REMIS Enterprise Model (Draft), Developed by Century Technologies, Inc., 12/31/92

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1 TICARRS User's Manual ,Vol. I, 9/30/90
2 TICARRS User's Manual, Vol. II, 9/30/90
3 TICARRS User's Manual, Vol. 1: Organizational Level, 1/15/93
4 TICARRS User's Manual, Vol. 2: Intermediate Level, 1/15/93
5 TICARRS User's Manual, Vol. 3: Query User's Manual, 1/15/93
6 TICARRS Functional Description, Vol. I, 9/1/88
7 TICARRS Functional Description, Vol. II, 3/1/90
8 TICARRS Functional Description, Vol. III, 9/1/88
9 TICARRS Functional Description, Vol. I, 1/15/93
10 TICARRS Functional Description, Vol. II, 1/15/93
11 TICARRS Functional Description, Vol. III, 1/15/93
12 Procedural Language Processor Manual F-16/F-15 1/90

E. Other

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2 Technical Manual: Maintenance Data Collection, TO 00-20-2

II. Program Reviews

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1 Minutes of the October 1991 CAMS Functional Review Board (FRB)
2 Minutes of the April 1991 CAMS Functional Review Board (FRB)
3 System Decision Memorandum (SDM) for CAMS, 6/4/90
4 Memorandum for Chairman, Automated Information Systems Acquisition Review Council (AISARC), Subject: System Decision Memorandum for CAMS, 1/26/88
5 Memorandum for AF/CV, Subject: CAMS System Decision Memorandum 6/17/87
6 Report of Audit, Operational Security of Standard Base-Level Computers by Air Force Audit Agency, 6/30/92, Project 91054015
7 Review of AVFuel Decentralization Test Project 92061006
8 Air Force Audit Agency Draft Report Processing Procedures
9 Audit Followup, Evaluation of CAMS Status and Inventory Subsystem Application Controls Project 91054020
10 Report of Audit, Evaluation of CAMS Status and Inventory Subsystem Application Controls by Air Force Audit Agency, 3/9/90, Project 9195417

11 Air Force Audit Agency Project 6195420—CAMS, Draft, 1987
12 Proposal for the Training and Certification of CAMS Data Base Managers, 3/25/93
13 SBLC Computer types by model number and associated performance ratings (e.g. MIPS) supplied by Gunter AFB
14 Listings of number of CAMS users vs. total SBLC during prime shift for all bases supplied by Gunter AFB
15 Summary of CAMS performance, number of PIDs and user transactions over the period Jan-Feb 1993 supplied by Gunter AFB
16 Listing of individual base average transaction rates and response times for the period Jan-Feb 1993 supplied by Gunter AFB
17 CAMS Optimization Enhancement Description supplied by Gunter AFB
18 Old Manning Information from Gunter AFB
19 List of Gunter personnel by organization
20 Requirement for CAMS Data Base Manager Cerification Course
21 Talking Paper for CAMS DMRD 924 Regionalization
22 Writeup on CAMS DBM Certification
23 CAMS Optimization Effort
24 CAMS TCTO Input Problem from Lockheed CSA, 7/793
25 CAMS TCTO Input Problem from Lockheed CSA, 6/3093
26 ADP Consolidation Program (DMRD 924), brifing by Mr. Arnold Regan SSC/SSR, 7/23/93

B. REMIS

1 REMIS Acquisition Program Baseline (APB), 7/30/91
2 REMIS Milestone III Documentation Requirements, 7/7/92
3 REMIS Recovered Functionality—Program Status, 2/92
4 EIMSURS and PPS Operational Assessment Plan, 8/92
5 REMIS RFB Statement of Work—Reference #:F33600-86-C-7004
6 Program Management Directive (PMD) for REMIS, 7/31/91
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9 LMSC/SZ Review: Checklist for REMIS, 9/21/90
10 REMIS Milestone I LOGSARC Minutes of 9/16/85 Meeting
11 LOGSARC Program Action Directive, 10/10/85
12 Equipment Maintenance Database Milestone 0 LOGSARC Minutes of 5/7/85 Meeting
13 EMDB Program Action Directive, 5/7/85
14 Analysis and Projection of the REMIS Performance Technical Operating Report #TOR-927-92 by Litton Computer Services, 9/16/92
15 Graphs showing REMIS user activity since 9/91 supplied by Litton
16 Documents supplied by Litton listing data error problems and corrective action being taken to resolve problems
17 F-16 TCTO Data Loss in REMIS from General Dynamics Fort Worth Division, 11/30/92
18 F-16 MDC Data Loss 3/8/93 from Lockheed Fort Worth Company
19 F-16 MDC Data Loss Verification from Lockheed CSA, 4/14/93
20 F-16 MDC Data Loss from Lockheed CSA, 5/20/93
21 F-16 MDC Data Loss from Lockheed CSA, 6/7/93
22 F-16 MDC Data Loss from Lockheed CSA, 7/7/93
23 F-16 MDC Data Loss Verification from Lockheed CSA, 7/7/93
24 F-16 MDC Data Loss Verification from Lockheed CSA, 7/12/93
25 F-16 MDC Data Loss from Lockheed CSA, 7/14/93
26 F-16 MDC Data Loss from Lockheed CSA, 7/30/93
27 REMIS Status Report—Week ending 19 Feb 1993, Subject: TICARRS vs. REMIS Flying Hours Comparisons

C. CAMS and REMIS

1 Program Management Directive (PMD) for the Integrated Weapon System Management CAMS and REMIS, 5/6/92
2 System Decision Memorandum (SDM) CAMS/REMIS, 6/2/92
3 SDM Status
4 Major Automated Information System: In-Process Review CAMS/REMIS, 5/13/92
5 CAMS/REMIS Acquisition Program Baseline (APB,) 1/12/93
6 CAMS/REMIS Special Report for IDA supplied by Litton, 3/30/93
7 US Air Force ADP Consolidation Program briefing from Gunter AFB
8 Responses to CAMS/REMIS Action Items from 27-29 Jan. 1993 IDA visit to REMIS PMO

D. TICARRS

1 TICARRS Trusted Security Level from DRC 8/4/93
2 TICARRS Capability Summary
3 Implementation Approach TICARRS 92
4 TICARRS Statement of Work FY91-94, 12/31/91
5 Draft: General Outline of the Assessment of TICARRS 92 at 4 Wing, Seymour Johnson AFB, NC, 3/9/93
6 TICARRS 92 Operational Assessment Project #:LM930561 AFLMA, 5/93
7 TICARRS Open Write-Ups, DRC, 5/20/93
8 TICARRS '92 Interface to Comprehensive Engine Management System Impact Analysis Draft, DRC, 5/20/93
9 Impact Analysis for SCN122 Maintenance Snapshot Inquiry by P. Bruce, DRC, 5/20/93
10 Impact Analysis for Modifications to the TICARRS PQDR Subsystem by Deborah S. Blair, DRC, 5/19/93
11 Impact Analysis: TICARRS/SBSS Interface Requirements
12 Impact Analysis: AGE
13 Impact Analysis: CAMS Screen380 (PMGT)
14 Impact Analysis: MPT
15 Impact Analysis: Automated Aircraft Forms
16 Revised summary of man-hours required for all Impact Analyses, 6/30/93
17 Draft estimate for SBSS/TICARRS Interface 6/25/93
18 Lines of Code estimates for Automated Aircraft Forms (781), 6/23/93
19 Lines of Code Estimate for 781 7/12/93
20 Lines of Code estimates for TICARRS Replicate CAMS/CEMS Functions, 6/22/93
21 Line of Code Estimate for SBSS/TICARRS Interface, 7/8/93
22 Line of Code Estimate for MPT dated 8 July 1993
23 Final Report TICARRS Test at Seymour Johnson AFB, 29 March-7 May 1993 by DRC, 5/21/93
24 Final Report on TICARRS 92 Data Initialization for the Operational Assessment conducted at Seymour Johnson AFB by DRC, 7/2/93
25 TICARRS 92 and Bad Actor Impact: An Analysis of Eliminating Bad Actors by DRC, 5/17/93
26 TICARRS Software Growth by DRC, 5/26/93
27 Lines of Code for Selected TICARRS Conversations by DRC, 5/17/93
28 Remaining DIREPs to be completed for TICARRS 92 effort; from R. Dallamora, DRC, 5/17/93
29 The Impact of Data System Accuracy on Detecting Bad Actors from DRC, 5/20/93
30 F-15 E Fleet Monthly Report, 12/92
31 F-15 E Fleet Monthly Report, 1/93
32 F-15 E Fleet Monthly Report, 2/93
33 F-15 Bad Actor Program by DRC, 2/93
34 F-15 TICARRS (G333) Maintenance Analysis Reports by DRC, 6/19/92
35 F-15 Radar System Bad Actor/CND Study APG-70 Performance Evaluation by DRC, 9/28/92

36 TICARRS Ad Hoc Query Programs Hermes' Portfolio, by Phillip Hermes ASD/ENSSR WPAFB, 5/91
37 Draft Copy of DRC's Analysis of the Data Problems at Seymour Johnson AFB from Jack Anderegg
38 Executive Summary: TICARRS 92 Data Initialization (Draft) from DRC
39 Report on TICARRS Data Initialization for Seymour Johnson AFB. Dynamic Research Corp., 6/8/93
40 F15 Operational Evaluational Statistics during Operational Assessment provided by DRC
41 Response to Item #3 supplied by DRC Subject: Errors or Bad Data in report
42 DRC standard procedures for estimating and configuration control
43 Description of Middleware supplied by DRC
44 Draft report assessing data load and data accuracy converting from CAMS to TICARRS for the Seymour Johnson test supplied by DRC
45 DRC response to IDA collected issues regarding the performance of TICARRS at Seymour Johnson test
46 Listing and Narrative of 149 DIREPS reported from test at Seymour Johnson supplied by DRC
47 Copies of 409 functional disconnects reported during test at Seymour Johnson supplied by DRC
48 TICARRS Labor Distribution (FY85-FY92) supplied by DRC
49 TICARRS F-15 DIREP Report (for Seymour Johnson) supplied by DRC
50 Manhours to support DIREPS from Seymour Johnson supplied by DRC
51 List of DIREPS (categorized by S/W Deficiency, S/W Mod, Data Issue, Security Access, Printing Issue, User Familiarity, Functionality Change,Other) supplied by DRC
52 Report on TICARRS Data Load for Seymour Johnson AFB supplied by DRC
53 TICARRS transaction rates during Seymour Johnson test supplied by DRC
54 F016 CDS Software Productivity Analysis

III. Cost Estimates

A. CAMS

1 CAMS Cost Benefit Analysis, 9/30/92
2 CAMS USAF-Wide Funding Status Chart, 9/92
3 Cost Figures for CAMS from LGM, 4/22/92
4 CAMS USAF-Wide Funding Status, supplied by Cliff Hall, 5/13/92
5 CAMS FY93 and Projected Manning
6 CAMS Prior Year Funding

B. REMIS

1 REMIS Independent Cost Estimate (ICE, 10/92
2 REMIS Development Costs and Operations and Support Costs, 4/92
3 REMIS Life-Cycle Cost Estimate, 11/8/91
4 REMIS Firm-Fixed Price Contract Structure, 3/24/92
5 REMIS Economic Analysis, prepared by Systems and Applied Sciences Corp., 11/27/85
6 REMIS Program Office Estimate (POE), 9/92
7 REMIS Program Office Estimate, 6/91
8 Cost/Benefits Analysis for REMIS FY93-FY02, 9/30/92
9 REMIS FY1992 Funding Execution Status, 5/4/92
10 REMIS Functional Economic Analysis, 9/13/91
11 REMIS Costs for Future Operations 1993-1998, supplied by Litton
12 Litton Document showing proposal to reduce overall hardware and personnel OandM costs while improving performance
13 REMIS Program Funding supplied by Cliff Hall, 5/13/92
14 REMIS PMO Prior Year Funding
15 REMIS Program Funding sheets supplied by The Stratos Group, Inc. on 7/1/93
16 Memorandum from Charlie Swett, Litton Computer Services, to Charles Crawford, Subject: Pricing for Tandem SAFEGUARD, 8/11/93

C. CAMS and REMIS

1 Memorandum of Agreement: Cost Documentation for CAMS/REMIS, 9/25/92
2 Memorandum of Agreement: Cost Documentation for CAMS-REMIS, 8/92
3 CAMS/REMIS FY93 and Out Funding

D. TICARRS

1 Cost Estimate for Activating the B-1B on TICARRS/SDS, 9/8/92
2 An Initial Business Case Analysis of TICARRS '92, 12/15/92
3 DD250s for FY87-FY91 Final Inspection and Receiving Reports
4 TICARRS Technical Cost Proposal/TICARRS-to-REMIS Data Conversion Task Order 92-016
5 Cost Analysis to Field TICARRS 92 Across 27 AF Systems and Com-Electronics by DRC, 5/25/93
6 TICARRS Software Estimates vs Actuals 28 May 1993 by DRC
7 Computer Cost for TICARRS 92 Testing and CAMS Enhancements Increment VI and Beyond, from Cliff Hall, 6/3/93
8 Document prepared by Hall organization Subject: Costs of expanding TICARRS scope and functionality
9 TICARRS preliminary write-up of cost to provide Maintenance Production management capability supplied by DRC
10 Letter to Betsy Bailey from Bruce Cooper Subject: Clarification of TICARRS Costs, 5/26/93
11 A Quote on DRC's Current Hardware Configuration from Dataguard Recovery Services, Inc., provided by DRC, 7/13/93

IV. Briefings and Presentations

A. CAMS

1 Trip to Europe briefing by Cliff Hall 3/1/93
2 Comparison of CAMS Reporting and CEMS Direct Line Reporting (DLR) of CEMS Data Feb. '92-Jan '93
3 CAMS Presentation on Unit CAMS History, CAMS Utilization, Individual Concerns, Local Improvement Measures, Mobile CAMS Terminals, Deployable Comm Package
4 CAMS Overview presented by John Hayes
5 DBM Concerns presentation; Subject: status and problems of supporting CAMS on site and proposed changes a la TICARRS supplied by Gunter AFB
6 Presentation by Bill Burson, Standard Systems Center, Subject: USAF ADP Consolidation Program

B. REMIS

1 Operational Assessment of REMIS: PPS and EIMSURS, briefing by Captain John Robinson, 12/92
2 REMIS Status Briefing to Mr. Majors, 2/19/92
3 REMIS Briefing to Mr. Dave Roberts, Subcommittee on Defense House Appropriations Comm. 7/22/91 by Lt. Col. Duane Johnson, REMIS PD
4 REMIS Joint Program Management Review. briefing by Cliff Hall 12/19/91
5 Air Force REMIS Assessment Report, 6/27/90
6 Why REMIS? briefing given to Mr. Rad by AFLC, 6/14/90
7 REMIS presentation to OSD Action Officers by AFLC, 9/19/90

C. CAMS and REMIS

1 Integrated Weapon System Management of CAMS/REMIS—IWSM Experience Report
2 CAMS/REMIS briefing by Clifford Hall, 5/13/92
3 CAMS/REMIS/CEMS: A Special Study, briefing by Wayne Fenwick, Litton Computer Services, 2/4/93
4 CAMS/REMIS Interface Design, briefing by Wayne Fenwick, Litton Computer Services, 5/26/93

D. TICARRS

1 Concepts of Operation: TICARRS and SDS Presentation by Clifford Hall, 8/17/92
2 Options for Implementation of Congressional Language, 12/24/92
3 Maintenance Information System Architecture for the Air Force of the Future, briefing by DRC, 9/92
4 TICARRS: The Solution To Two-Level Maintenance Information Requirements briefing by DRC
5 TICARRS Presentation to Institute for Defense Analyses by Dynamics Research Corporation, 7/28/93

E. CAMS, REMIS, and TICARRS

1 TICARRS Presentation to Cynthia Kendall by DRC, 9/9/92
2 CAMS, REMIS, TICARRS briefing by Clifford Hall ,9/92
3 Briefing by Cliff Hall, "The Air Force"

F. Other

1 Coronet Deuce Phase III—Progress Briefing, 1/21/93-2/3/93
2 Integrated Maintenance Information System (IMIS), briefing by Robert C. Johnson, Armstrong Laboratory
3 CASS AX Interchange Meeting by Ray Lebeau, NSWC/CARDEROCK, 1/15/93
4 OC-ALC/LAH B-52/Missiles Division, Reliability and Maintainability Briefing Presented by Pamela Herzog
5 F-22 Advanced Tactical Fighter (ATF) Integrated Maintenance System AIMS Briefing by Major Ralph Lowry, F-22 Support Data Integrated Product Team Leader, Wright Patterson AFB, 3/20/93
6 F-15E Can-Not-Duplicate (CND) Failure Reduction Study Program Completion/Recommendation Briefing by McDonnell Aircraft Company, 4/21/92
7 IMIS: Integrated Maintenance Information System briefing 1/26/93 by GDE Systems Inc.
8 IMIS Briefing by General Dynamics Electronics Division, 6/4/93
9 F-22 Advanced Tactical Fighter (ATF) Integrated Maintenance System AIMS briefing by Major Ralph Lowry, Wright Patterson AFB, 3/30/93

V. Correspondence

A. CAMS

1 Memorandum For The Record from Stan Horowitz, Subject: The perspective on CAMS from the B-1 wing at Grand Forks AFB, 2/3/93
2 Memorandum For AF/SC, Subject: Operational Security of Standard Base Level Computers, 5/14/92
3 Letter from Lockheed Configuration Status Accounting (CSA) to HQ MSC/SR and HQ SSC/LGM Subject: CAMS TCTO Reporting, 3/25/93

B. REMIS

1 OSD Consolidated TandE Comments on REMIS Test and Evaluation Master Plan (TEMP), 10/26/92
2 Review Comments on REMIS TEMP by David A. Dore, 11/13/92
3 REMIS Program Director's Comments, 3/31/92
4 Memo regarding REMIS Security Test and Evaluation (STandE), 2/7/92
5 REMIS Functional Requirements Board Meeting Minutes, July 16-17, 1991
6 DCSO/DISDA Letter: Defense Data Network (DDN) x.25 Qualified Host Interfaces, 8/23/91
7 DISA Certificate of Tandem DDN Access Method (DDNAM)
8 Impact Statement on REMIS Termination
9 Memo to Dev Devers from Kathleen Jablonski Subject: Action Item #6 from Jan. 1993 IDA Visit to REMIS PMO (Maintenance Data Reject Rate), 4/19/93
10 ACC message from Kathy Jablonski Subject: REMIS Access at Unit Level, 4/6/93
11 Memo to M. Olds from D. Rose; Subject: Analysis of accuracy rate for aircraft transactions in REMIS

12 List of IDA's data requests to Cliff Hall

13 Memorandum from Thomas King, Litton, to Waynard Devers, IDA, Subject: IDA Action Item Responses, 7/30/93

C. CAMS and REMIS

1 Memo on REMIS: . ' ' MS/REMIS Interface Testing and System Reporting Designator (SRD) Table Upload

2 A Chronology o. User Concerns and Complaints about CAMS and REMIS, 2/12/93

3 Impac: Statement on Proposed CAMS/REMIS Termination, 9/23/91

4 Le:ter by Tom King; Subject: Data Errors in CAMS/REMIS

5 Memorandum for Chairman, Costs/Benefits Review Group

D. TICARRS

1 Report of Trip to DRC about TICARRS 92 by LGMPE, 12/92

2 Memo regarding TICARRS Demonstration by DRC and CAMS, 12/17/92

3 Letter from DRC to Cliff Hall, Subject: Interface Definition Support Requirements, 1/5/93

4 Letter from DRC to John Milligan, Subject: Visits needed for info. on additional functionality, 1/12/93

5 Memo: Costing Proposal to Move TICARRS to DDN, 9/11/92

6 Memorandum from MSC/SR to HQ USAF, Subject: TICARRS Program Information Request 7/24/92 and TICARRS Statement of Work FY91-94

7 Letter from Donald E. Desrochers to Dev Devers 5/13/93 Subject: Listing of Action Items resulting from 10-11 May 1993 meetings at DRC

8 Letter to MSGT Randy Diebold from Ray Pruett, TICARRS Field Operations 5/26/93 Subject: TICARRS Contract F33600-90-D-0360-0004, Field Engineer Support

9 Message referring to 14 April 1993 Letter from TICARRS PMO concerning Follow-On Contract 5/26/93

10 DRC's comments on IDA memos

11 Memo from DRC to Cliff Hall; Subject: Interface Requirements for CEMS and SBSS

12 Memo from DRC to Gilligan; Subject: CEMS and SBSS Interface Requirements

13 Memo for the Record from Pat Kelley (DRC) to Bill Florac (IDA) Subject: Request for TICARRS Backup/Recovery Information, 7/12/93

14 Memo for the Record from Pat Kelley (DRC) to Betsy Bailey (IDA) Subject: Request for TICARRS Information, 7/12/93

15 Memo from John Nowak, HQ USAF/LG, to John Anderegg, DRC, Subject: General Officers Working Group, 7/6/93

E. CAMS, REMIS, and TICARRS

1 Letter from DRC to Cynthia Kendall in regard to 9/9/92 presentation, 9/11/92

2 Memorandum of Understanding Between CAMS/REMIS and DRC regarding TICARRS 12/17/92

3 ACC Position Paper, Subject: Switching from CAMS/REMIS to TICARRS '92, 12/4/92

4 A Response to the Suggestion that CAMS should be bypassed and data inputted directly into TICARRS by Tom King, Litton Computer Services

5 Memorandum of Agreement: Reconciling TICARRS and CAMS/REMIS Functionality

6 Letter from Barry Phillips, Genesis Software Applications to IDA 5/27/93 Subject: Funding data for CAMS/REMIS/TICARRS

F. Other

1 "New Approach Identifies Malicious System Activity" Major Patrick Phillips, USAF, Signal, 3/92

2 Equipment Maintenance Database PAR-LOG-LOL-085-333, 8/84

3 Data Automation Requirement for Contractual Service, 9/83

4 Statement of Work for the Development of Integrated Maintenance Management System (IMMS) 1984

5 Letter from Tandem Computers Incorporated; Subject: Tandem System National Computer Security Center C2 Evaluation, 4/7/92

6 Draft "Leading Edge" Article: Technology Insertion
7 SSC/AQ Request for Waiver to Allow Use of Group User-ID/Passwords 1/23/90 and HQ USAF/SCT Response Letter, 4/6/90
8 CAMS/REMIS-TICARRS Considerations and Estimated Financial Implications from David A. Dore OASD, 9/14/92
9 AF wasted millions on computer technology, report says by Jim Abrams, AF Times, 1/4/93
10 Memo from ASC/YF to IDA, Subject: Information Required by IDA to Complete Study "A Comparison of CAMS/REMIS and TICARRS" (AIMS Development Costs), 6/11/93
11 Memorandum for ASD(C3I), Subject: Comments on Draft IDA Comparison of CAMS/REMIS and TICARRS, 7/30/93
12 Official OSD Comments on IDA Paper P-2863, "A Comparison of Air Force Data Systems" from Robert T. Mason, Assistant Deputy Under Secretary (Maintenance Policy)
13 Memorandum for Director, Maintenance Policy, ODUSD (Logistics) Subj: IDA Review Version Report "A Comparison of Air Force Data Systems," 7/21/93
14 Memorandum for Director, Maintenance Policy, ODUSD (Logistics) from David Dore, Subject: IDA Review Version Report "A Comparison of Air Force Data Systems," 7/30/93
15 Memorandum for Director, Maintenance Policy from Francis L. McDonald, Staff Analyst, Force Structure and Infrastructure Cost Analysis Division Subject: IDA Report on CAMS/REMIS and TICARRS, 7/26/93
16 Comments on IDA Paper P-2863 "A Comparison of Air Force Data Systems" by Litton Computer Services (Final Version), 7/26/93
17 Comments on IDA Paper P-2863 "A Comparison of Air Force Data Systems" by Litton Computer Services (Draft Version), 7/23/93
18 Comment on IDA Report "A Comparison of Air Force Data Systems" by Dynamics Research Corporation, 7/23/93

VI. System Reports and Screens

A. CAMS

1 CAMS data base schema and associated stats. supplied by Gunter AFB
2 CAMS Menu and slides showing CAMS WCE processing supplied by Gunter AFB
3 Copies of LOC for CAMS software supplied by Gunter AFB
4 CAMS Main Menu Directory

B. REMIS

1 Copies of REMIS-EIMSURS screens, 1/26/93
2 Copies of REMIS-GCSAS screens, 11/10/89
3 Copies of REMIS-PPS screens, 1/25/93
4 Examples of REMIS Reports: AV/Trainer Status/Utilization Report, Assignment/Possession Report

C. TICARRS

1 TICARRS PLP Samples
2 TICARRS Canned Query Samples
3 Description/Purpose of TICARRS screens
4 Examples of TICARRS Data Outputs from Phil Hermes
5 Data Sheets describing TICARRS statistics, i.e. database size, transaction rates, computer type, back up procedures, COTS software elements (supplied by DRC)
6 TICARRS data base diagrams and schema listing supplied by DRC
7 Number of screens by week (and daily averages) for Seymour Johnson supplied by DRC

VII. House Appropriations Committee Report Language for CAMS/REMIS and TICARRS

A. FY93 HAC Report Language

1 Impact Information Regarding FY93 HAC Report Language on CAMS/REMIS and TICARRS 9/9/92, 9/4/92

2 Memos from Kathleen Jablonski to Dave Dore, Subject: Your Questions to FY93 HAC Language, 9/11/92
3 DRC's Response to FY93 HAC Report Language on CAMS, REMIS, and TICARRS, 9/14/92
4 Memo from Kathleen Jablonski to Dave Dore regarding HAC FY93 Language, 8/14/92
5 REMIS and TICARRS Direction 8/10/92 from Robert Heath (Robbins-Gioia) to MSC/SR
6 SAC Defense Subcommittee Results, 9/16/92
7 GAO Correction Plan 9/4/92
8 Responses to OSD Questions from MSC/SR, 9/9/92
9 DASD(IS) Memo, 7/31/92
10 DoD Appropriations Bill, 1993 p.38-41, 238-239
11 DoD Appeal FY93 Defense Appropriations Bill, 9/4/92
12 Cynthia Kendall's Questions and 3 Sets of Replies
13 DRC's Response to SPO "Impact Information Regarding FY93 HAC Report Language on CAMS/REMIS and TICARRS, 8/18/92
14 Response to OSD Questions by SPO "Impact Information...", 9/9/92
15 DRC's Response to SPO's Response
16 DRC Response to OSD Questions Regarding TICARRS, 8/17/92
17 DRC Response to OSD Question #3—TICARRS Funding Profile FY87-FY91
18 1992 Robbins-Gioia, Inc. Documentation for the Study of CAMS/REMIS/TICARRS
19 DoD Concerns about FY93 House Comm. on Appropriations Report Language on CAMS/REMIS
20 TICARRS CBD Notice for FY93, 9/11/92

B. FY92 HAC Report Language

1 CAMS/REMIS Concerns in DoD FY92 Appropriations Conference Report
2 FY92 Appropriations Bill Conference Report 102-328, 9/18/91
3 Letter from GAO/IMTEC regarding House Report 102-328, FY92 Appropriations Bill Conference Report
4 FY92 Appropriations Bill SAC Report

VIII. Miscellaneous Reports

1 Maintenance Data Collection Review (On-Equipment Failure Data) by Air Force Logistics Management Center, Gunter AFB, 10/91
2 Depot Maintenance Management Information System Benefit Analysis and Combat Capability Assessment: Summary and Conclusions by Synergy, Inc., 5/25/88
3 52nd Fighter Wing: Aircraft Maintenance Summary 12/92
4 Deployable Log C2 Requirements Capability Technical Report by Booz-Allen and Hamilton, Inc., 1/92
5 Concept of Future: Air Force Logistics Maintenance Information Systems—Draft, 9/25/92
6 Maintenance Data Collection Documents for IDA from OC-ALC/FMI, 3/9/93
7 Depot Maintenance Automated Data Systems by Financial Management Directorate Warner Robins ALC
8 VFL Recommendations/Comments on McAir Silver Bullet Study
9 RandM 2000 Field Data Requirements for a SPO Operation by Phillip Hermes ASD/ENSSR NAECON 92 Paper, Dayton, OH, 5/21/92,
10 NAECON 92 Information Systems in the User Environments RandM 2000 Field Data Requirements for a SPO Operation Briefing 21 May 92 by Phillip Hermes ASD/ENSSR WPAFB
11 Hermes' Perspectives on Field Data Issues Jan. 93 by Phillip Hermes ASC/ENSSC WPAFB
12 FDTS Field Data Tracking Systems for Program Offices (AFSC and AFLC) by Phillip Hermes 1984 RandM Workshop McClellan AFB
13 Total Quality Management and Field Data Systems by Phillip Hermes
14 The Quality Flyer Special Edition "Survey Says...", 3/93
15 Reports on Squadron Centered Logistical Systems supplied by DRC

16 GAO Report: Air Force ADP Lax Contract Oversight Let to Waste and Reduced Competition, 11/92
17 IMIS Initital Estimates of System-Wide Costs and Benefits: An Executive Summary by Dr. Burke Burright, Capt. Bradley Lloyd (Armstrong Laboratory), and John Zawila, Robbins-Gioia, Inc., 5/93

IX. Memos for the Record from IDA Study Team

1 Memo for the Record from Karen Tyson, 5/13/93, Subject: Visit with Air Vehicle Data Officers-REMIS Users on 3/30/93
2 Memo for the Record from Karen Tyson, 5/6/93, Subject: Trip Report for Visit to SPO's and IMIS Lab on March 29 and 30, 1993
3 Memo for the Record from Lee Dymond, 5/6/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
4 Memo for the Record from Lee Dymond, 4/7/93, Subject: DRC data on F-16s and F-15s
5 Memo for the Record from Lee Dymond, 4/8/93, Subject: Observations of Work Centers at S-J AFB Pre- and Post-TICARRS—Plans and Scheduling
6 Memo for the Record from Lee Dymond. 4/8/93, Subject: Observations of Work Centers at S-J AFB Pre- and Post-TICARRS—Engine Management
7 Memo for the Record from Lee Dymond, 4/8/93, Subject: Observations of Work Centers at S-J AFB Pre- and Post-TICARRS—Maintenance Instruction
8 Memo for the Record from Stan Horowitz, 5/4/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
9 Memo for the Record from Lee Dymond, 5/4/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
10 Memo for the Record from W. C. Devers, 5/5/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
11 Memo for the Record from Lee Dymond, 5/5/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
12 Memo for the Record from Stan Horowitz, 5/5/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
13 Memo for the Record from Lee Dymond, 5/5/93, Subject: Modifications to TICARRS needed to give it the functions of CAMS
14 Interoffice Memo from Lee Dymond, 6/2393, Subject: SBLC costs provided by Mr. Jesse B. Smith HQ ACC/SCMD
15 Memorandum for the Record from Stan Horowitz, IDA, Subject: Possible schedule for the introduction of TICARRS on a fleet-wide basis, 7/28/93

APPENDIX C

QUESTIONNAIRES ADMINISTERED DURING THE OPERATIONAL ASSESSMENT AT SEYMOUR JOHNSON AFB

1993 AIR FORCE CAMS USER QUESTIONNAIRE

PURPOSE OF QUESTIONNAIRE

The Air Force, through the Office of the Secretary of Defense, has asked the Institute for Defense Analyses (IDA) to conduct an independent analysis of two major Air Force information systems—CAMS/REMIS, and TICARRS. IDA needs to understand the ways people use the information systems in their jobs and their reactions to the systems. The assessment that is beginning at 4th Wing provides a unique opportunity to do this. As a user, you can provide us with valuable information about your experiences with the systems. This brief questionnaire, which should take less than 10 minutes to complete, asks you for this information about CAMS.

Your name and phone number would allow us to reach you if we have questions about your response. However, this is entirely optional. Only aggregated responses, not individual ones, will be reported.

Work Center_______________ Work Center Code________ Rank____ AFSC:_____

Shift (circle): Day Mid Swing Name (optional)____________ Phone (optional)______

INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE

- Make heavy black marks that fill the circle for your answer.
- Unless otherwise specified in the instructions for a question, only one answer should be marked.

BACKGROUND INFORMATION

IN THIS SECTION, YOU WILL BE ASKED QUESTIONS ABOUT YOUR BACKGROUND AND PAST INFORMATION SYSTEM USE.

1. What is your current paygrade?

O E-1 to E-3	O O-1 to O-3	O WG-1 to WG-6
O E-4 to E-5	O O-4 to O-6	O WG-7 to WG-11
O E-6 to E-7	O O-7 and above	O WG-12 and above
O E-8 and E-9		

2. If you perform any of the following functions, please indicate:

O Debrief

O Flight line crew chief

O Plans and scheduling

O Flight line engine maintenance

O Database management

O Analysis

3. What is the *highest* school grade or academic degree that you have completed?

O Less than 12 years of school (no diploma)

O GED or other high school equivalency certificate

O High school diploma

O Some college, but did not graduate

O 2-year college degree (AA/AS)

O 4-year college degree (BA/BS)

O Some graduate school, but no post-graduate degree

O Post-graduate degree

4. How long have you been using computers (any type--mainframes, PCs, word processors, etc.)?

O 6 months or less

O Between 6 months and 2 years

O Over 2 years

5. Do you have a personal computer at home?

O Yes

O No

INFORMATION SYSTEMS EXPERIENCE

6. **How satisfied are you with the following aspects of CAMS? Mark only one answer for each item.**

	Very Satisfied	Satisfied	Mixed/ Neither	Dissatisfied	Very Dissatisfied	Does not apply/ Don't Know
Ease of use, understandability	O	O	O	O	O	O
Ability to input data easily	O	O	O	O	O	O
Ability to get data out easily	O	O	O	O	O	O
Ability to modify previously input data	O	O	O	O	O	O
Usefulness of training	O	O	O	O	O	O
Usefulness of manuals, documentation	O	O	O	O	O	O
Ability to help me perform my duties	O	O	O	O	O	O
Performance of functions I really need	O	O	O	O	O	O
Performance of functions that are optional for me	O	O	O	O	O	O
Availability when I need it	O	O	O	O	O	O
Ability to input data quickly	O	O	O	O	O	O
Ability to get data out quickly	O	O	O	O	O	O
Usefulness of reports generated from CAMS	O	O	O	O	O	O
Accuracy of data obtained	O	O	O	O	O	O
Overall satisfaction with CAMS	O	O	O	O	O	O

	Less than 1 month	1-6 months	6 months 1 year	1-3 years	More than 3 years	Does not apply/ Don't Know
Length of time you have used CAMS	O	O	O	O	O	O

	More than once a day	Daily	A few times a week	A few times a month	A few times a year	Does not apply/ Don't Know
How often do you use CAMS	O	O	O	O	O	O

	Under One	One	Two	Three	Four	Over four
Hours spent using CAMS during a normal workday	O	O	O	O	O	O

Are you a hands-on user of CAMS (that is, you use the terminal yourself to input data or get data out)? Yes No

Are there particular features of CAMS that make it easy to use?

Yes No

____

____

____

____

Have you had any problems using CAMS? Yes No
If yes, what kinds of problems? Be specific.

Do you use CAMS reports in your job? Yes No
If yes, which reports?

Do you ever find it necessary to verify reports against another source?
Yes No
If yes, give details.

7. Have you ever used TICARRS or F-16 CDS or F-117 Smart Data System?
If yes, how satisfied were you with the system?

	Very Satisfied	Satisfied	Mixed/ Neither	Dissatisfied	Very Dissatisfied	Does not apply/ Don't Know
Overall satisfaction	O	O	O	O	O	O

8. Does your job generally involve inputting data, outputting data, or both?

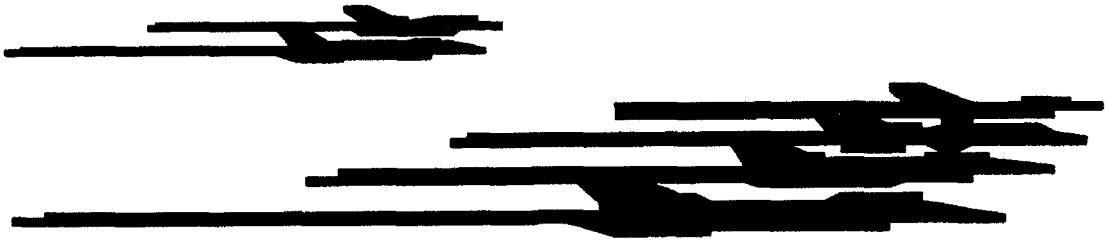
O Inputting data
O Outputting data
O Both inputting and outputting data
O Using data obtained from someone else

9. In general, which of these statements comes CLOSEST to describing how important CAMS is to performing your job? Mark only one answer.

O I could not do my job without the system.
O Without the system, I could do my job, but it would be extremely difficult.
O Without the system, I could do my job, with some additional time or cost required.
O The system is nice to have, but it is not critical to my job.
O I could do my job more easily without the system.

10. If you have comments about CAMS or TICARRS please write them here.

WEEK 6 TICARRS ASSESSMENT QUESTIONNAIRE



PURPOSE OF QUESTIONNAIRE

The Air Force and the Institute for Defense Analyses (IDA) need your help in the assessment of TICARRS at 4th Wing. As a user, you can provide us with valuable information about your experiences with TICARRS. This questionnaire should take less than 10 minutes to complete.

Your name and phone number would allow us to reach you if we have questions about your response. However, this is entirely optional. Only aggregated responses, not individual ones, will be reported.

Work Center____________________ Work Center Code__________ Rank__________

AFSC:________________Today's Date______________________________________

Shift (circle): Day Mid Swing Name(optional)______________ Phone(optional)__________

INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE

- *Make heavy black marks that fill the circle for your answer.*
- Unless otherwise specified in the instructions for a question, mark only one answer.
- For Yes/No questions, please circle the appropriate response.
- Some questions ask for a written reponse rather than blackening a circle. In such cases, write responses in the spaces provided.

BACKGROUND INFORMATION

1. What is your current paygrade?

O E-1 to E-3	O O-1 to O-3	O WG-1 to WG-6
O E-4 to E-5	O O-4 to O-6	O WG-7 to WG-11
O E-6 to E-7	O O-7 and above	O WG-12 and above
O E-8 and E-9		

2. If you perform any of the following functions, please indicate:

O Debrief

O Flight line crew chief

O Plans and scheduling

O Flight line engine maintenance

O Database management

O Analysis

3. What is the *highest* school grade or academic degree that you have completed?

O Less than 12 years of school (no diploma)

O GED or other high school equivalency certificate

O High school diploma

O Some college, but did not graduate

O 2-year college degree (AA/AS)

O 4-year college degree (BA/BS)

O Some graduate school, but no post-graduate degree

O Post-graduate degree

4. How long have you been using computers (any type--mainframes, PCs, word processors, etc.)?

O 6 months or less O Between 6 months and 2 years O Over 2 years

5. Do you have a personal computer at home?

O Yes O No

S/.TISFACTION WITH TICARRS

6. **How satisfied are you with the following aspects of TICARRS? Mark only one answer for each item.**

	Very Satisfied	Satisfied	Mixed/ Neither	Dissatisfied	Very Dissatisfied	Does not apply/ Don't Know
Ease of use, understandability	O	O	O	O	O	O
Ability to input data easily	O	O	O	O	O	O
Ability to get data out easily	O	O	O	O	O	O
Ability to modify previously input data	O	O	O	O	O	O
Usefulness of training	O	O	O	O	O	O
Usefulness of manuals, documentation	O	O	O	O	O	O
Ability to help me perform my duties	O	O	O	O	O	O
Performance of functions I really need	O	O	O	O	O	O
Performance of functions that are optional for me	O	O	O	O	O	O
Availability when I need it	O	O	O	O	O	O
Ability to input data quickly	O	O	O	O	O	O
Ability to get data out quickly	O	O	O	O	O	O
Usefulness of reports generated from TICARRS	O	O	O	O	O	O
Accuracy of data obtained	O	O	O	O	O	O

	Very Satisfied	Satisfied	Mixed/ Neither	Dissatisfied	Very Dissatisfied	Does not apply/ Don't Know
Overall satisfaction with TICARRS	O	O	O	O	O	O

	Less than 1 month	1-6 months	6 months 1 year	1-3 years	More than 3 years	Does not apply/ Don't Know
Length of time you have used TICARRS	O	O	O	O	O	O

	More than once a day	Daily	A few times a week	A few times a month	A few times a year	Does not apply/ Don't Know
How often you use TICARRS	O	O	O	O	O	O

	Under One	One	Two	Three	Four	Over four
Hours using TICARRS during a normal workday	O	O	O	O	O	O

Are you a hands-on user of TICARRS (that is, you use the terminal yourself to input data or to get data out)? Yes No

Are there particular features of TICARRS that make it easy to use? Yes No
If yes, please provide details on these features:

____

____

____

Have you had any problems using TICARRS? Yes No
If yes, what kinds of problems? Be specific.

____

____

____

Do you use TICARRS reports in your job? Yes No
If yes, which reports?

____

____

____

Do you ever find it necessary to verify reports against another source? Yes No
If yes, give details.

____

____

____

7. **How satisfied were you with <u>CAMS</u> (the maintenance data system used by 4th Wing before this assessment)?**

	Very Satisfied	Satisfied	Mixed/ Neither	Dissatisfied	Very Dissatisfied	Does not apply/ Don't Know
Overall satisfaction with CAMS	O	O	O	O	O	O

Please compare how satisfied you are with TICARRS relative to CAMS. For each aspect, consider whether TICARRS is better or worse than CAMS.

	Much better than CAMS	Somewhat better than CAMS	Mixed/ Neither	Somewhat worse than CAMS	Much worse than CAMS	Does not apply/ Don't Know
Ease of use, understandability	O	O	O	O	O	O
Ability to input data easily	O	O	O	O	O	O
Ability to get data out easily	O	O	O	O	O	O
Ability to modify previously input data	O	O	O	O	O	O
Usefulness of training	O	O	O	O	O	O
Usefulness of manuals, documentation	O	O	O	O	O	O
Ability to help me perform my duties	O	O	O	O	O	O
Performance of functions I really need	O	O	O	O	O	O
Performance of functions that are optional for me	O	O	O	O	O	O
Availability when I need it	O	O	O	O	O	O
Ability to input data quickly	O	O	O	O	O	O
Ability to get data out quickly	O	O	O	O	O	O
Usefulness of reports generated from TICARRS	O	O	O	O	O	O
Accuracy of data obtained	O	O	O	O	O	O
Overall satisfaction with TICARRS relative to CAMS	O	O	O	O	O	O

8. Does your job generally involve inputting data, outputting data, or both?

O Inputting data

O Outputting data

O Both inputting and outputting data

O Using data obtained from someone else

9. In general, which of these statements comes CLOSEST to describing how important TICARRS is to performing your job? Mark only one answer.

O I could not do my job without the system.

O Without the system, I could do my job, but it would be extremely difficult.

O Without the system, I could do my job, with some additional time or cost required.

O The system is nice to have, but it is not critical to my job.

O I could do my job more easily without the system.

10. If you have comments about CAMS or TICARRS please write them here.

APPENDIX D

IDA TEST OF REMIS FUNCTIONALITY AND SELECTED OPERATING CHARACTERISTICS

APPENDIX D

IDA TEST OF REMIS FUNCTIONALITY AND SELECTED OPERATING CHARACTERISTICS

BACKGROUND

This appendix describes the results of an IDA test of REMIS functionality and status performed in late May 1993. This test supported several parts of our report, including the sections in Chapter V on functionality and operating characteristics, and Chapter VII on costs. There were four major reasons for this detailed review of REMIS:

(1) There has been congressional concern (generated at least in part by General Accounting Office oversight studies) about the progress and ultimate operation of REMIS. These concerns are partly responsible for this study.

(2) Through visits to several bases, two depots, and one Major Command (MAJCOM), we were able to observe CAMS, REMIS, and TICARRS in operation early in the study. Because there are few REMIS users (relative to projections of use after full operational capability is reached), we had fewer opportunities to observe its use than we had to observe the use of CAMS and TICARRS. Although formal operational test and evaluation was conducted for the Product Performance Subsystem (PPS) and the Equipment Inventory, Multiple Status and Utilization Reporting Subsystem (EIMSURS) of REMIS, the Air Force has not yet issued its report, so we could not use that as a basis for our analysis. Formal demonstrations are not a complete substitute for observing a system in actual use.

(3) To support our inquiry into the impact of information systems on weapon system logistics measures and mission capability, we requested historical data from both the REMIS and TICARRS Program Management Offices (PMOs). The TICARRS staff provided the requested data within about two weeks; but the REMIS staff could not completely fulfill the request, and we had to look to other sources (e.g., hard-copy data from the Air Combat Command).

(4) At the time of the test, MAISRC III for REMIS was scheduled for September 1993. IDA's limited observations of REMIS in actual use raised questions about the reasonableness of that schedule. (In fact, the schedule has since been pushed back.) REMIS's status and schedule had to be determined in order for IDA to make realistic cost estimates.

For all these reasons, IDA decided to make a more detailed assessment of the current functionality and status of REMIS and to compare TICARRS's and REMIS's data output capabilities. We gave the CAMS/REMIS PMO and the F-15 System Program Office (SPO) the same two data requests in late May 1993. The first data request was submitted three days before our arrival; the second was given upon our arrival at the respective Dayton, Ohio, offices. The requests (shown in Figures D-1 and D-2) covered several aircraft types, and the data requested are typical of those we had seen requested by base, Air Logistics Center (ALC), and MAJCOM users. The test focused on both: (1) the basic functions of REMIS and (2) specific areas of functionality that TICARRS users have requested be provided before TICARRS would be fully replaced by CAMS/REMIS.

The responses to the IDA data requests are summarized in Tables D-1, D-2, and D-3. "No data found" means that we were provided with a record of a query, but the system had no data. "Not provided" means that the response did not include a query for that ite: .. "No capability" means that the system does not have the capability to perform the query.

SEYMOUR JOHNSON DATA—GENERAL CAPABILITY OF THE SYSTEMS

Both REMIS and TICARRS were able to provide basic statistics—mission-capable rates and possessed hours—for the F-15E aircraft, 4th Fighter Wing, at Seymour Johnson AFB. Possessed hours agreed within 1 percent in the two data systems, while mission capable rates agreed within 0.1 percentage point (see Table D-3). However, REMIS found no data for March and April of 1993.

The reason for this lack of data is relevant to the technical and schedule status of CAMS/REMIS. In December 1992, the CAMS/REMIS PMO began implementing an initiative to allow for hourly updates to EIMSURS through the Defense Data Network (DDN), rather than the daily updates available through Autodin. Initial implementation of the initiative—dubbed Recovered Functionality (RECFU) II because it recovered planned functionality that had to be delayed due to funding cuts—precipitated a host of problems for REMIS users. REMIS functions that had been working fine stopped working. We received reports of problems from users at Hill AFB, Tinker AFB, Lockheed, and from a group of MAJCOM Aerospace Vehicle Distribution Officers. When we visited Oklahoma City ALC, REMIS users there were unable to demonstrate important functions to us, because of RECFU II. The effort to recover from RECFU II took six months. It involved removing blocks of historical data from the EIMSURS module of REMIS and replacing it with data

from CAMS, to ensure that CAMS and REMIS had the same data. Thus, certain historical data were unavailable at times, including some of the items we requested.

REMIS Data Request—21 May 1993

1. Monthly, October 1992 through April 1993, for F-15E aircraft, 4th Wing:
   A. Mission-capable rates number and percent of aircraft FMC, PMC, and NMC
   B. MTBF and MTBMA by two-digit WUC
   C. Re-test OK rates by two-digit WUC
   D. MMH/FH by two-digit WUC
   E. Break rates
   F. Fix rates
   G. Abort rates—In-flight and before-flight

2. For all F-15s, worldwide, and for WUC 74 for first quarter 1993:
   –Overall MTBMA
   –Listing of all LRUs, by serial number, with more than three maintenance actions in first quarter 1993
   –Listing of all LRUs, by serial number, with MTBMA less than overall group average

3. For F-16, part number 1829003, for May 92 through April 93, list:
   Serial number, WUC (14DPO and 14DQO), tail number, total sorties, total maintenance actions, total maintenance man-hours, number of failures, number of removals, number of CNDs, number of repairs, number of NRTSs, narratives.

4. Algorithms in REMIS and REMISTALK for calculation of MC rates, MTBR, MTBCF.
   Example run comparing variables drawn from REMIS and REMISTALK to see whether or not they are the same.

Figure D-1. 21 May 1993 Data Request

CAMS/REMIS Data Request—26 May 1993

1. List of current TCTOs for B-1 from GCSAS
2. Seymour Johnson LANTIRN and backshop automatic test equipment status
3. For December 1992, F-16C/D at ACC:
   Mission-capable rates
   Flying hours
   Sorties
   Maintenance man-hours per flying hour
   Mean time between maintenance actions—Type 1, Type 2, Type 6
   Total number of aircraft
   Total man-hours
   Total failures
4. Approved and actual configuration for any tail number of the B-1
5. From CAMS, number of transactions, by month, January 1991 to latest available, for 4th Wing at Seymour Johnson AFB and 388th Fighter Wing at Hill AFB

Figure D-2. 26 May 1993 Data Request

Table D-1. Summary of Responses to First Data Request

Item Requested	REMIS	REMIS Subsystem	TICARRS	Notes
1. Monthly, Oct 92-Apr 93, for F-15E, 4th Wing:				See Table D-3.
A. Mission-capable rates, number and percent of aircraft FMC, PMC, and NMC	Provided except Mar, Apr 93	EIMSURS	Provided	March and April 93 status data not available in REMIS due to RECFU II reconciliation. Except for these periods, data are very similar in both systems.
B. MTBF and MTBMA by 2-digit WUC	Not provided		Provided	
C. Re-test OK rates by 2-digit WUC	Not applicable		Not applicable	Dropped from analysis.
D. MMH/FH by 2-digit WUC	Not provided		Provided	
E. Break rates	No capability		Provided	REMIS does not have these capabilities. PMO promises they will be added around the 1st quarter 1994.
F. Fix rates	No capability		Provided	
G. Abort rates, in-flight and before-flight	No capability		Provided	
2. For all F-15s, worldwide, for WUC 74, first quarter 1993:				
A. Overall MTBMA	2.93	REMISTALK	11.3	REMIS data was for 4th quarter 1992 (not the time period asked for); data appear to include all maintenance actions. TICARRS provided for U.S. only (not worldwide as asked for). TICARRS number includes only Type 1 maintenance actions, verified inherent actions.
B. Listing of all LRUs, by serial number, with more than three maintenance actions in first quarter 1993	See note	PPS	Provided	REMIS PPS provided a different report that identified the high ten man-hour consuming systems.
C. Listing of all LRUs, by serial number, with MTBMA less than overall group average	See note		Provided	For the F-15C, these were WUCs 11000, 74FU0, 23ZO0, 65BA0, 24AD0, 74FA0, 76HF0, 76HA0, 24AN0, and 74KA0.

Table D-1. Summary of Responses to First Data Request (Continued)

Item Requested	REMIS	REMIS Subsystem	TICARRS	Notes
3. For F-16, part number 1829003, for May 92 through April 92, list:				
Serial number	No data found	PPS	Provided	PPS was queried only for 4th quarter 1992; found no data.
WUC (14DPO, 14DQO)	No data found	PPS	Provided	PPS was queried only for 4th quarter 1992; found no data.
Tail number	No data found	PPS	Provided	PPS was queried only for 4th quarter 1992; found no data.
Total sorties	Not provided		Provided	
Total maintenance actions	24		157, 116	REMIS data was for 1st quarter 1992 (not the time period asked for).
Total maintenance man-hours	13.2		316, 287	REMIS data was for 4th quarter 1992 (not the time period asked for).
Number of failures	Not provided		Provided	
Number of removals	Not provided		Provided	
Number of CNDs	Not provided		Provided only through narratives; DRC reps say number is minimal	
Number of NRTSs	Not provided		Provided only through narratives; DRC reps say number is minimal	
Narratives	Not provided		68 provided	
4. Algorithms in REMIS and REMISTALK for calculation of MC rates, MTBR, MTBCF. Example run comparing variables drawn from REMIS and REMISTALK to see whether or not they are the same.	Not provided		TICARRS definitions provided	REMIS PMO says that algorithms are different. They are waiting for an Air Force policy decision before making them uniform.

Table D-2. Summary of Responses to Second Data Request

Item Requested	REMIS	REMIS Subsystem	TICARRS	Notes
1. List of current TCTOs for B-1 from GCSAS	Provided	GCSAS	Not applicable	TICARRS does not support the B-1.
2. Seymour Johnson LANTIRN and backshop automatic test equipment status	Not provided	Not applicable		
3. For December 1992, F-16C/D at ACC:				
Mission-capable rates				
FMC hours	348,364	EIMSURS	382,532.4	
FMC percent	91.90%		89.53%	
Flying hours	10,636.5	EIMSURS	10,618.2	
	No data found	REMISTALK		
Sorties	7,699	EIMSURS	7,694 7,821	TICARRS gave two numbers, the first based on debrief records, and the second based on utilization records.
Maintenance man-hours per flying hour	4.71	REMISTALK	10.37	
Mean time between maintenance actions			1.01	
Type 1	2.71	REMISTALK	2.16	
Type 2	2.71	REMISTALK	6	
Type 6	3.26	REMISTALK	2.75	
Total number of aircraft	1,141	EIMSURS	574.3	REMIS appears to give total for all major commands, TICARRS gives average possessed aircraft for ACC.
Total man-hours	26,104.2	REMISTALK	110,093.5	REMIS man-hours are on-equipment only
Total failures	8,087	REMISTALK	10,537	
4. Approved and actual configuration for any tail number of the B-1 GCSAS developers indicated that approved configuration for the B-1 is not yet complete. Actual configurations have not yet been loaded into GCSAS.	Not provided		Not applicable	TICARRS does not support the B-1.
5. From CAMS, number of transactions, by month, January 1991 to latest available, for 4th Wing at Seymour Johnson AFB and 388th Fighter Wing at Hill AFB.	Not provided		Provided	

Table D-3. Detail on Item 1 of First Data Request

	Oct-92	Nov-92	Dec-92	Jan-93	Feb-93	Mar-93	Apr-93
A. Mission-capable rates							
FMC hours							
REMIS	47,815.0	46,100.0	48,123.0	49,551.0	43,610.0	53,578.0	50,452.7
TICARRS	47,647.2	46,138.4	48,570.1	49,232.8	43,405.1	47,555.6	43,737.0
Percent FMC							
REMIS	84.1	84.2	86.2	88.8	86.5	100.0	100.0
TICARRS	84.3	85.0	87.0	88.2	86.2	89.4	88.4
B. MTBMA, Type 1—WUC 74, fire control							
REMIS				Not provided			
TICARRS	8.88	8.74	7.82	9.01	10.37	11.48	8.75
MTBMA, Total—WUC 74, fire control							
REMIS				Not provided			
TICARRS	3.73	3.56	3.31	3.18	4.21	4.52	3.56
C. Re-test OK rates			Dropped from analysis—no depot at Seymour Johnson AFB				
D. MMH/FH—WUC 74, fire control							
REMIS				Not provided			
TICARRS	2.28	2.37	2.58	2.66	2.38	1.78	2.01
E. Break rate, total							
REMIS				No capability			
TICARRS	26.56	9.04	9.55	11.24	9.08	9.01	7.89
F. Fix rate							
REMIS				No capability			
TICARRS	87.5	82.9	83.7	77.6	82.8	79.0	83.0
G. Abort rates							
REMIS				No capability			
TICARRS	3.8	2.7	0.1	0.0	0.0	0.0	0.0

REMIS did not provide the additional Seymour Johnson data we asked for on MTBF and MTBMA.

SERIAL NUMBER TRACKING AND TRACKING FOR WARRANTIES

Items 2 and 3 in the first data request addressed the issue of serial number tracking. TICARRS users say that serial number tracking is necessary for identifying bad actors and removing them from the system.

As background information, we asked for data on MTBMA for F-15s, and both REMIS and TICARRS provided reasonable data. The TICARRS data were only for U.S. aircraft, not F-15s worldwide, as requested.

We asked for all serial numbers within WUC 74 (fire control) that had more than three maintenance actions during the first quarter of 1993. TICARRS was able to provide this; REMIS provided an alternative report that listed the top ten man-hour consuming systems for the F-15C by WUC, not by serial number.

We also asked for data and maintenance narratives on the F-16 rotary flap actuator, a part that is tracked by TICARRS for warranty purposes. The only data provided by REMIS were maintenance actions and man-hours at the WUC level. TICARRS provided 68 complete narratives to illustrate its capability. The REMIS PMO told us that narratives can be retrieved through REMISTALK, but they did not provide us with a sample. The REMIS developers are working to provide retrieval of narratives through a standard PPS query in a future update, currently promised for first quarter of FY 1994.

ALGORITHMS FOR CALCULATION OF MAINTENANCE PARAMETERS

TICARRS users have complained that the algorithms in REMIS's PPS, EIMSURS, and REMISTALK for calculation of MC rates, MTBR, and MTBCF are not consistent with one another. The REMIS PMO's explanation was that different groups of users have different methods of calculating these variables. Developers have decided to wait for an Air Force policy on what the algorithms should be, and they will then be standardized across all modules. However, discussions within the Air Force about standardizing algorithms have been under way for at least 10 years. There is no reason to think that a standardized Air Force policy will be issued in the near future.

GCSAS ISSUES

We asked for several items from GCSAS in the second request (items 1, 2, and 4). Although it is not yet fully operational, we wanted to get a sense of its progress. GCSAS was able to provide a list of current Time Compliance Technical Orders (TCTOs) for the B-1 (an aircraft not supported by TICARRS), but was not able to provide a list of approved and actual configuration for the same aircraft, because the actual configuration had not yet been loaded. Sample screens provided to us looked reasonable, but we could not assess how GCSAS would work with real data.

BASIC F-16C/D DATA

In our second data request (item 3), we asked for basic F-16C/D data. Both systems were able to provide most of the data we wanted. REMIS supplied only on-equipment man-hours, not total. TICARRS supplied two estimates of sorties, one that was similar to the REMIS number and was based on debrief records and a second, which users say is more accurate, that was higher and was based on utilization reports. There were some major differences in the numbers.

The reported maintenance man-hours per flying hour from REMISTALK (4.71), was inconsistent with the reported on-equipment maintenance man-hours and flying hours (26104.2/10636.5 = 2.45). The TICARRS-reported MMH/FH of 10.37 was consistent with its reported components.

In other cases of differences in magnitudes, it was impossible to determine which system—REMIS or TICARRS—had the correct data.

CAMS DATA REQUEST

Item 5 in our data request was directed toward CAMS data for the purpose of the Seymour Johnson assessment and is not relevant to our assessment of REMIS.

OBSERVATIONS

In several cases, the REMIS data provided were for a different time period than requested, which prevented us from comparing the REMIS data with the TICARRS data. In one instance, TICARRS provided data for U.S. F-15s only, rather than worldwide, so we could not compare the data directly. REMIS provided some C-141 data not relevant to our request. (REMIS output on the C-141 is obtained through an interface with G081; the C-141 fleet does not use CAMS.)

With regard to ease of use, the difficulty of pulling data from the three parts of REMIS was obvious. Developers of the different parts of REMIS had to confer to determine which module was the best one to use.

Furthermore, the people who retrieved the data for our test were experts. An average user would probably encounter even more difficulty. Aggregation—the ability to get a single bottom-line total without all the components—is difficult in the canned queries in the EIMSURS and PPS. In many cases, REMISTALK, the customized inquiry utility, was the only way to retrieve aggregate data without a lot of extraneous output, and REMISTALK response times are considerably longer than those for standard queries.

The TICARRS data were retrieved by DRC representatives more easily and promptly than the REMIS data could be retrieved by REMIS developers. The TICARRS data were provided on letter-sized laser-printed paper and included a roadmap through the data. The REMIS response was on wide-carriage paper and was very difficult to follow.

In summary, REMIS demonstrated some basic functions reasonably well (e.g., mission-capable rates) but did not consistently demonstrate other basic functions such as retrieval of total maintenance man-hours and mean time between maintenance actions. This raises questions about the realism of the schedule for full implementation of REMIS. REMIS did not demonstrate serial-number tracking or narrative retrieval, capabilities that TICARRS users say they need. Algorithms for calculation of key maintenance parameters are not uniform within REMIS. IDA personnel found the TICARRS output much easier to follow than the REMIS output.

APPENDIX E

THE FUTURE AIR FORCE

APPENDIX E

THE FUTURE AIR FORCE

This appendix explores the adaptability of CAMS/REMIS and TICARRS to the future operating environment and condition of the Air Force. Evaluating adaptability of these systems requires a vision of the future Air Force.

The nature of the future Air Force with respect to factors that affect the operation and effectiveness of maintenance information systems is certainly subject to debate. However, that vision is constrained by resources and technology. Since change in the Air Force does not occur overnight, our vision of the future is heavily weighted by current Department of Defense and Air Force initiatives. Alternative visions of where the Air Force will be in the future are not necessarily inconsistent with the analysis that follows.

Three categories of factors provide the proper perspective for a discussion of where the Air Force will be in the next seven to ten years:

- operational policies and practices,
- resource constraints, and
- technology path (the ways in which technology is expected to evolve).

OPERATIONAL POLICIES AND PRACTICES

We expect that operational policies and practices will move toward less reliance on forward-deployed forces, centralized control of air assets as demonstrated in Desert Shield/Desert Storm, and increased reliance on fewer levels of maintenance to support operating units.

The bulk of U.S. forces will be CONUS-based, and will be required to deploy quickly and on short notice to locations that may lack significant infrastructure and support. This deployment environment will be dominated by squadron-level deployments to the theater of operation and requires that logistics support be available at the time of deployment, be easily transportable, ruggedized, and self-supporting.

After the units are deployed, the air campaign will be undertaken with centralized command and control that directs the application of air power from composite wings and

new combinations of air power assets (CONUS-based bombers, land-based deployed aircraft and naval aircraft). As in Desert Shield/Desert Storm, the theater air commander will develop the air campaign and give daily operational orders to the units under his command.

The implications for logistics support are that the theater air commander will need access to accurate and timely information on the readiness of air assets under his control, requiring a single information source (central data base) to speed complex information flows. This deployment environment also requires that information systems easily interface with each other, offering a sense of seamlessness in supply, distribution, maintenance, and transportation. CONUS-based support for this deployment scenario will depend on rapid and effective communications with the theater of operation.

Finally, the operational organization of the Air Force may change in ways that make some kinds of information more important than they used to be. The adoption of composite wings with several different types of aircraft and increased reliance on two-level maintenance to support the different aircraft types is an example of such a change. In Coronet Deuce, the application of two-level maintenance for avionics and engines to selected F-16 units, the Air Force identified a need for asset visibility to provide support to the operational units. Asset visibility includes having information to track demands for spare parts, maintenance actions, transportation and processing of repairable assets at the depots, identification of bad-actor components, and testing of software incompatibilities between levels of maintenance.[1]

The effect of these policies is that the maintenance data system will need to support the deployment of squadron-level units and to provide information to the theater air commander to support execution of the air campaign, to support deployed units in peacetime and conflict, and to support the application of two-level maintenance to a wider segment of weapon systems.

RESOURCE CONSTRAINTS

Resource constraints mean that the future Air Force will have a significantly smaller force structure and that operating with reduced support and personnel in the logistics tail will be desirable. Two-level maintenance, a way of cutting the tail, will place a premium on

[1] Both two-level maintenance and composite wings involve performing more maintenance at locations other than the base where a part was found to fail. Quick and effective access to reliable fleet-wide maintenance history data may be more important under such circumstances.

data in the maintenance data system. Maintenance histories and other information will have to be more accessible and accurate than in the past because the Air Force will not have the opportunity to buy excess spare parts as a deliberate response to uncertainty about actual requirements. Better information on the status of assets, including their location while they are moving through the transportation system, will be needed. Fewer assets in the system also requires that those assets be highly reliable and easily maintainable and supportable. This will place increased emphasis on being able to identify support problems and justify the resource expenditures to correct the problems. The maintenance data system will have to provide the information to identify problems and justify the resources to fix them.

TECHNOLOGY PATH

The third consideration is the technology path, that is, what kinds of technological change can be expected, notably in the weapon systems being supported and in the information system development and operational environment. The following subsections address some of characteristics of technological change that seem realistic.

Emerging Weapon System Technology

Weapon systems will become increasingly complex, software-intensive, and reliable. Increased emphasis will be placed on providing built-in test capability in the aircraft to diagnose the nature of equipment problems. The maintenance data system should be able to accept electronic information on failure modes and circumstances directly from the aircraft. Similarly, test equipment at all levels of maintenance should be able to communicate (send and receive information) directly to the maintenance data system.

Weapon systems such as the F-22 will rely on integrated diagnostics to ensure support of the weapon system. Integrated diagnostics will be needed to address support problems with the evolving integrated digital avionics and distributed sensor systems [electro-optical and radio frequency (RF) technologies]. In the case of digital avionics, the built-in test/self-test (BIT/ST) capability will generate large amounts of detailed information that will be provided to a maintenance data system. The information will be needed to assess the health of the integrated digital avionics system and to determine when to replace line replaceable modules that are characterized by graceful degradation. Evolving RF systems include solid state, active aperture, and phased-array technologies that use large numbers of transmit/receive units and have significantly improved reliability. The RF systems will also be characterized by graceful degradation and will rely on BIT/ST to help determine when sufficient transmit/receive units have failed and affect system performance.

This process will generate information that will be stored in a maintenance data system. This information will assist in determining when systems are failing to meet performance requirements, assist in trouble-shooting problem systems, and allow proper maintenance decisions relative to bad-actor identification efforts.

The amount and complexity of software and integrated circuits, driven by advances in micro-circuitry, will increase dramatically, placing new demands on configuration management, testing, and repair. Maintenance technologies will require more emphasis on software support as weapon systems become more software-intensive. The software-intensive systems of the future will raise issues of how to measure software effectiveness, not only operationally but environmentally. How does the reliability of the software relate to the reliability of the hardware platform? The maintenance data systems will collect information on the performance of the systems to help segregate performance problems among the hardware, operational flight software, and maintenance software. The maintenance data system will provide the link from the problems that are experienced during operation of the weapon system to the test equipment performing maintenance tests and to the maintainer operating the testing system. Also, the operating units, Major Commands, and engineers or technicians monitoring the health of a system will rely on this information to identify bad-actor components and candidate systems for modifications and software improvements.

Expert systems that aid in the identification, diagnosis, and repair of weapon systems will be available. Automated maintenance aids, such as Integrated Maintenance Information System (IMIS), that use expert-system techniques may become widely available, replacing technical manuals, and aiding in troubleshooting the weapon system. In some cases, expert-system software may aid the evolution of the testing strategy and improve test programs through the use of artificial intelligence techniques. These techniques will partially rely on data in the maintenance information system such as failure histories, maintenance histories, and narrative accounts of the operational or testing problems. In either case, these aids will benefit from direct access to maintenance-history data that should reside in the maintenance information system.

Evolving Information System Technologies

Over the past several years, we have witnessed significant improvements in price/performance ratios in technological areas that are key to the future design of information systems. For example:

- Solid-state technology continues to improve and large volumes of even higher densities and faster devices are being produced with each new generation of chip. Reduced power requirements, new packaging, and better cooling techniques contribute to the ability to use the chips in a wide variety of applications and environments. High-technology production processes have resulted in high-yield, low-cost chip production.

- Communication technologies are taking advantage of fiber optics to provide higher bandwidth facilities at lower cost, making it possible to reliably transmit and receive increasingly larger quantities of high-resolution digital data at low cost.

- Computer technology is taking advantage of advances in communications and solid-state technology in several ways. Faster and more dense solid-state devices lead to faster and more powerful general-purpose computers. Computers that used to be considered large scale are now small in size and power consumption, and even larger in computing power. According to technology experts, this trend is likely to continue for the remainder of this decade, resulting in significantly lower price/performance ratios, and computers that will provide the equivalent of large-scale power at mini-computer prices. Personal computers, only recently becoming useful and popular as laptops, are now headed for hand-held model production. Hand-held computers coupled with a short-range radio or cellular transmitter and the use of multimedia technology *(see below) offer new* opportunity for dramatically more efficient and reliable data collection and workload scheduling and monitoring.

- Data storage technology has developed along two fronts. Magnetic storage is continuing on the path of increased density and smaller footprint devices at all levels, resulting in the ability to economically store large volumes of readily accessible data. Optic technology offers "write once, read many" (WORM) technology, which is being used for storing huge quantities of text and graphical data on compact disk, leading to more effective distribution of reference materials, documents, and the like.

- Software engineering and programming technology, while seemingly not moving as fast as other technological areas, has in fact been able to take advantage of the newest hardware technologies and has made significant progress towards instituting predictable and productive engineering-like disciplines and technologies. Instituting programming process management and measurement disciplines has resulted in significantly improved productivity, quality, and adherence to schedules of software development activities. The development of object-oriented software and databases offers opportunities for software reuse and improved quality. Expert systems technology, or rules-based software systems, are becoming more prevalent in

applications involving diagnostic or decision assistance. The availability of affordable communications and storage, and low-cost computer chips has lead to both the development of economically feasible and highly user-friendly graphical interfaces and the introduction of mixed media (sound, voice, imaging, graphics, and text) to communicate with the users. The software industry, realizing the road to success is to allow for interchangeability, is racing towards supporting open systems and industry standards.

While the technology will continue to make advances, prudent managers of existing information systems are establishing strategies that will allow them to take advantage of the technology as it matures without revamping the entire information system. They are looking to evolve to the new technologies rather than revolutionize the process and systems currently in place.

The weapons maintenance information system of the future needs to have the following strategically important features:

- deploy at the squadron level;
- adapt to new weapon systems, maintenance technology, tools and procedures;
- interface with other systems;
- adapt to Air Force organizational changes and processes;
- provide accurate and timely data;
- provide user-friendly (productive and efficient) data collection and data access;
- be economically feasible (affordable) to operate;
- accommodate evolving information system and data automation technologies;
- provide centralized data for fleet-wide perspective of status, reliability and maintainability data; and
- sustain high system reliability and performance characteristics.

Figures E-1 and E-2 illustrate a weapons maintenance configuration that takes advantage of current information systems technology and has those features.

The configuration shown in Figure E-1 is based on providing squadron-level modularity by using local area networks (LANS) and client-server data base (CSDB) systems. Each squadron has its own CSDB, LAN, work stations, and test stations to record and evaluate maintenance data. The squadron-level database has access to and may be accessed by both a wing CSDB and a central data repository. Essential fleet-wide data are gathered from the squadron by the repository system. The repository system is immediately available to the squadron user or for fleet-wide data. Communication between

the squadron data base (SQDB) and the repository is via high-speed fiber-optic communication links on wide area or local area networks (WAN/LAN). This allows the repository to not only transmit and receive data from the nodes on the link, but also maintain the programs and operation of the squadron CSDB, obviating the need for a computer operations staff at each squadron. The squadron has access to similar client servers or gateways on the link, so that appropriate data may be exchanged between complementary systems [e.g., Comprehensive Engine Management System (CEMS), fuel, and Combat Communications System (CAS-B)]. In turn, the central repository will support major functional units such as repair depots and technical data distribution centers through direct links or WAN communication systems. The technical data distribution centers prepare, maintain, and distribute optical compact disks to the squadrons based on weapon and equipment ownership.

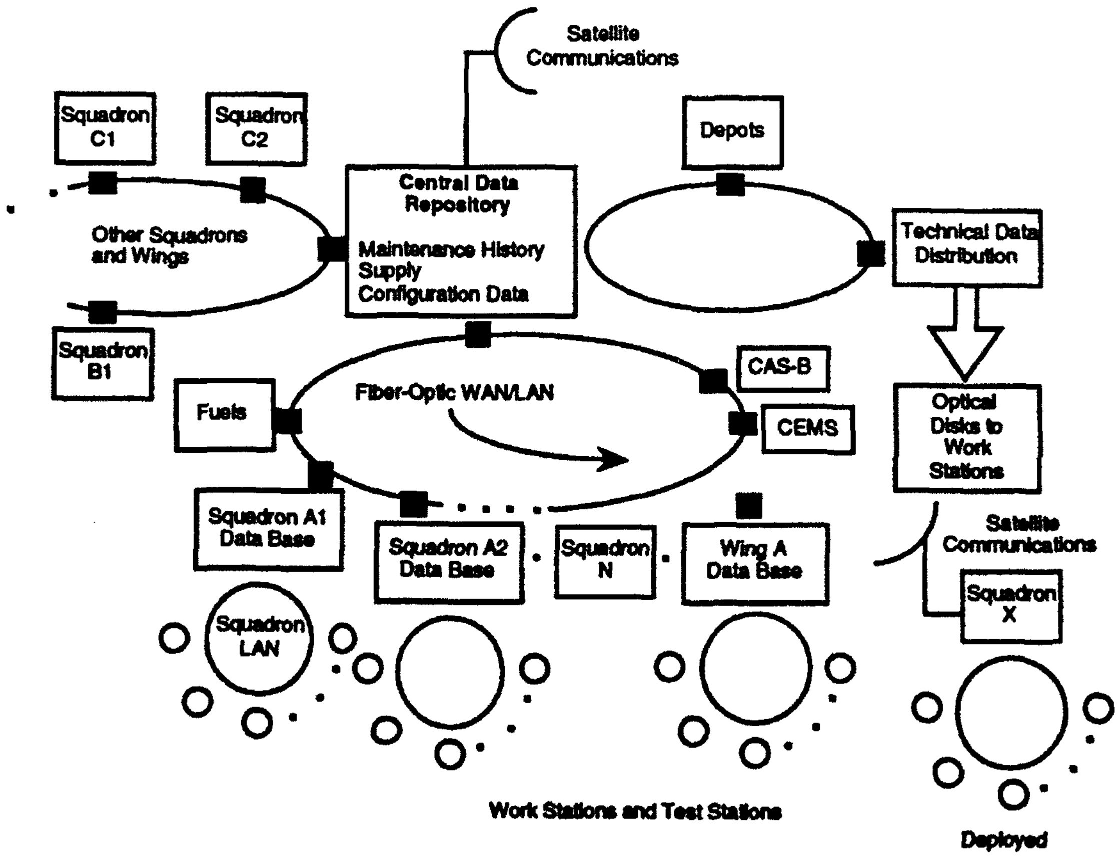


Figure E-1. Future Weapons Maintenance Information System

Deployed squadrons also use the CSDB LAN system configuration, but are able to sustain operation without continuous communication to the central repository, since the CSDB contains all the data relevant to a deployed situation. The deployed squadron will

periodically use satellite links to communicate essential data to and from the central repository.

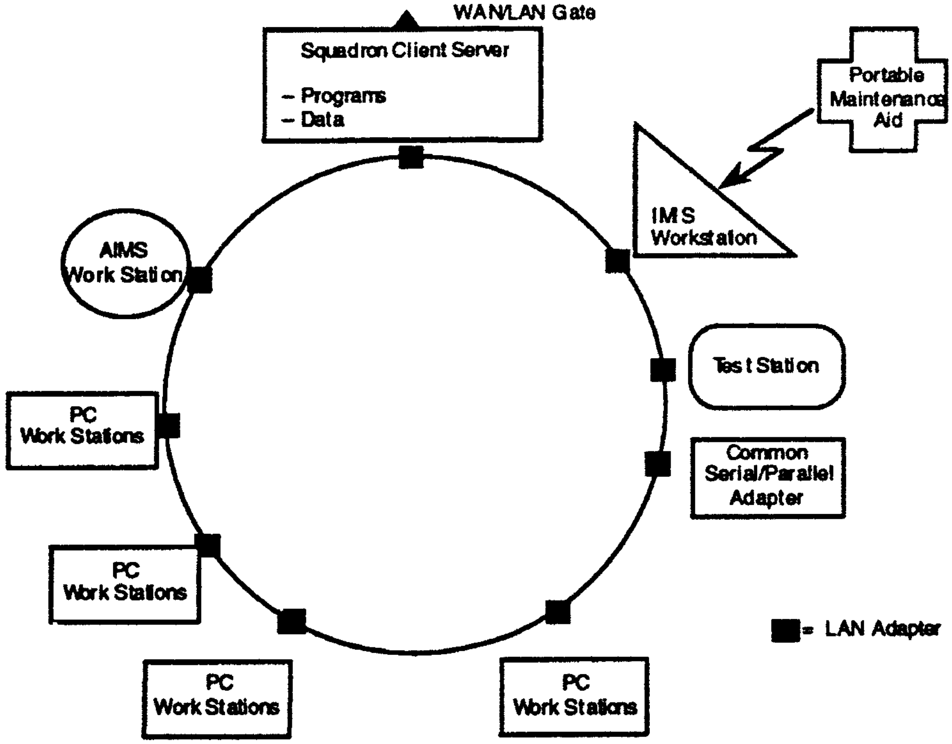


Figure E-2. Future Squadron-Level Weapons Maintenance Information System

At the squadron level (Figure E-2), LANs are used to communicate with a variety of work stations and test stations, all of which use a standard LAN adapter and common serial/parallel interface. The addition of new test or terminal equipment is facilitated by using standard interfaces and common communication protocols. Personnel entering maintenance data are provided data-entry windows that allow selection of appropriate data (e.g., part-serial numbers) from lists rather than by entering the information manually. This practice will reduce both data-entry errors and the time technicians spend at the terminal. Forthcoming diagnostic data-collection devices, both hand-held and integrated, interface with the LAN adapter to send data to the CSDB and to be evaluated by diagnostic expert systems at the work stations. Powerful personal computer terminals have graphic displays and voice response units that allow not only the data analyzers to easily see the trends of maintenance data, but provide help and guidance to the novice and those in training.

APPENDIX F

EFFECTS OF INFORMATION SYSTEMS ON WEAPON SYSTEM PERFORMANCE

APPENDIX F

EFFECTS OF INFORMATION SYSTEMS ON WEAPON SYSTEM PERFORMANCE

A. OBJECTIVE

This appendix describes the effect (or lack of effect) of CAMS/REMIS and TICARRS on weapon system performance and maintenance-related support. The objective is to determine if these information systems significantly affect the operational and support environment. If they do, the comparison of CAMS/REMIS to TICARRS takes on mission-critical dimensions; if not, these information systems' evaluation moves one step closer to a pure cost comparison.

A comparison is made of performance and support over the period of time when TICARRS users were required to switch from direct entry into TICARRS to entry through CAMS and then into TICARRS. Weapon systems supported by TICARRS are the focus here but two non-TICARRS weapon systems are included to control for any simultaneous Air Force activities.

B. APPROACH

The approach is to use a time series of weapon system and product performance data for tactical weapon systems to create a baseline or historical snapshot from which the conversion from direct-entry TICARRS reporting to CAMS-entry TICARRS reporting can be evaluated. The CAMS conversion dates are then "overlaid" onto these trends to determine if there are significant differences in pre- and post-CAMS conversion performance. Formal statistical tests are used to evaluate these time trends.

Data requests were made of Dynamics Research Corporation (DRC) and the CAMS/REMIS Program Management Office (PMO) to provide the following information:

- inventory, status, and utilization data for tactical weapon systems over the period 1982 through 1992 and

- product performance data, including failures, demands, maintenance man-hours, and so on, by two-digit work unit code (WUC) for these weapon systems.

DRC provided these data for all F-15 and F-16 weapon systems on the TICARRS system. The CAMS/REMIS PMO provided recent weapon system performance data only, for F-111s, F-4Es, and other weapon systems. A similar request to Air Combat Command (ACC) provided hard copies of more historical data for non-TICARRS weapon systems.

The weapon system performance data were used to calculate a measure of operational readiness, the mission-capable rate (MC), defined as

$$MC = (FMC + PMC)/\text{possessed hours},$$

where FMC means fully mission capable and PMC means partially mission capable.

The product performance data supplied for the F-16 and F-15 systems by DRC were used to calculate mean time between failures (MTBF) for types 1, 2, and 6 failures and maintenance man-hours per flying hour (MMH/FH).

Two models are developed and tested to evaluate weapon system performance in the context of the information systems. The first model focuses solely on the F-16 weapon system and its conversion from TICARRS direct entry to entry through CAMS that occurred during the period late 1988 through 1989. A regression model of the following form is developed:

$$y\ (MC) = f(CAMS, T86\text{–}T92, e),$$

where

MC = the mission capable rate;

CAMS = the (wing-specific) conversion date from TICARRS to CAMS;

T86-T92 = a series of dummy variables taking the value 1 in the year indicated and 0 otherwise; and

e = the error term.

The second model focuses on three weapon systems, the F-16, F-111, and F-4E, all of which had increasing (or at least non-decreasing) MC rates over the relevant period of this evaluation. The key independent variable in all these equations is a period measure that identifies three time periods: (1) the time before conversion to CAMS, (2) the period during which all F-16 bases were converted to CAMS entry, and (3) the period after the conversion.

A series of regression models were developed with the following functional form:

$$y\,(MC) = f(P_i, e), \tag{F-1}$$

$$y\,(MTBF_1) = f(P_i, e), \tag{F-2}$$

and

$$y\,(MMH/FH) = f(P_i, e) \tag{F-3}$$

where,

MC = the mission capable rate, defined above;

$MTBF_i$ = the inherent failure rate for selected two-digit WUCs (engines and avionics);

MMH/FH = the maintenance man-hour measure defined above;

P_i = a set of three 0–1 dummy variables where $P_1 = 1$ from January 1985 through September 1988, 0 otherwise; $P_2 = 1$ from October 1988 through May 1990, 0 otherwise; and $P_3 = 1$ from June 1990 through the end of the time series, 0 otherwise; and

e = the error term.

Equation (F-1) was run separately for the F-16, F-4E, and F-111 weapon systems. The coefficients on the dummy variables were compared across the different weapon systems. The latter weapon systems were used in the analysis to provide a control group against which the TICARRS reporting weapon system could be evaluated. If the F-16 results are found to be significantly different from the other two aircraft types, the conversion to CAMS may have had an impact on weapon system performance. If not, cost becomes a more important driver of the CAMS/REMIS and TICARRS comparison. Equations (F-2) and (F-3) were run for F-16 data only. These equations measure the impact of the CAMS conversion on product performance support. No similar data for the other two weapon systems were available for comparable testing. Ordinary least squares (OLS) regression techniques were used. In all three cases [equations (F-1), (F-2), and (F-3)], the pre-CAMS period (dummy variable P_1) was chosen as the omitted category.

C. DATA ANALYSIS

Data were evaluated for all active Air Force F-16As and F-16Cs on the TICARRS system in the first model and for F-16s, F-111s, and F-4Es on the CAMS/REMIS system for the second model, over the period 1985 to 1992. The analysis is conducted by wing (and by mission, design, series in the second model). The tables provided are examples of the basic system data used in this analysis.

After some casual observation of the data, regression models were implemented and evaluated. OLS estimates were derived and the equations were evaluated for statistical estimation problems. The results for the first model are shown in Table F-1.

Table F-1. Model 1: F-16

Weapon System:	F-16
Dependent Variable:	MC
Independent Variables:	Coefficient (T-Ratio)
Intercept	0.83 (84.05)
CAMS	0.006 (.462)
T86	-0.016 (-1.231)
T87	0.013 (0.999)
T88	0.063 (4.84)
T89	0.056 (3.45)
T90	0.067 (3.98)
T91	0.068 (3.86)
T92	0.064 (3.57)
Adjusted R^2 =	0.0813

The coefficients on T88 to T92 are statistically significant at the .99 level. The coefficient on CAMS is not statistically significant.

The results of this first model indicate that the conversion to CAMS did not significantly affect the MC rate of the F-16. While the MC rates were changing over the seven years, those changes are indicative of time changes, not any conversion from TICARRS entry to CAMS entry. The results show an MC rate of about 83 percent with statistically significant increases over the years 1988 to 1992. The CAMS variable is not at all significant to changes in the MC rate.

The results for the second model are shown in Table F-2. All of the coefficient estimates are significant at the .99 level except P_2 for the F-111, which is significant at the .975 level.

Table F-2. Model 2: F-16, F-111, and F-4E

Weapon System:	F-16	F-111	F-4E
Dependent Variable:	MC	MC	MC
Independent Variables:	Coefficient (T-Ratio)	Coefficient (T-Ratio)	Coefficient (T-Ratio)
Intercept	0.84 (183.50)	0.68 (94.10)	0.85 (226.58)
P_2	0.051 (7.06)	0.030 (2.56)	0.021 (3.06)
P_3	0.062 (9.67)	0.093 (9.10)	0.032 (4.14)
Adjusted R^2 =	0.0656	0.260	0.082

The results of this series of regression models indicate that there is no statistically significant difference in the MC rates of the three weapon systems. The estimates for P_3 show the F-16 value between the value for the other two weapon systems, and all are significant. The conclusion is that conversion to CAMS did not significantly affect weapon system performance.

A number of regression models were run to determine if the conversion to CAMS affects MTBF or MMH/FH for WUC 74, fire control and inertial navigation system. For the MTBF measure, a CAMS conversion indicator variable and variables designating each year was implemented. The CAMS conversion variable was not statistically significant. A second model that employed a time trend was not statistically significant. The results of a third model using dummy variables that signify time periods (P_2 and P_3 as previously described) are shown in Figure F-3. For the MMH/FH measure, the equation with the CAMS conversion dummy showed no statistical significance for the CAMS variable. Relative to 1987, the years 1988 through 1991 show statistically significant (negative) coefficients, although the values of the coefficients for 1989, 1990, and 1991 varied little, indicating no significant difference in MMH/FH between those three years. The time periods version (P_2 and P_3) is shown below.

Figure F-3. Model 3: F-16 (MTBF) and F-16 (MMH/FH)

Weapon System:	F-16	F-16
Dependent Variable:	MC	MC
Independent Variables:	Coefficient (T-Ratio)	Coefficient (T-Ratio)
Intercept	2.325 (10.86)	4.06 (3.63)
P_2	-0.824 (2.17)	-2.850 (1.58)
P_3	-0.135 (0.45)	-0.382 (0.28)
Adjusted R^2 =	0.001	0.007

Those two equations determine whether there is any statistical significance between the CAMS and post-CAMS conversion periods relative to the pre-CAMS period using two measures of product performance, MTBF and MMH/FH.

Both intercepts are significant and P_2 in the MTBF equation is also. There is a definite decline in MTBF in the 1988-1989 period. However, no significant change in MC rate occurred. The tracking of flying hours is so closely monitored in the Air Force that one can assume that the observed trend is not due to a decline in flying hours. Observation of a series of plots confirms this assumption. A logical explanation might be an increase in the

number of transactions entered into the system during the conversion period. However, previous views of conversions to CAMS saw a drop in transactions reported in the system. Such a drop would produce a positive effect on MTBF, not negative. It appears that this finding is time-specific and not related to the CAMS conversion.

D. RESULTS

The results of the analysis presented above indicate that consistently across bases and wings, the conversion to CAMS-entry from direct-entry TICARRS for the F-16 weapon system produced no significant change in weapon system performance. Compared to the F-111 and F-4E, there are no differences in MC rates during the period of conversion to CAMS entry for the F-16. Regarding product performance of a selected WUC for the F-16 aircraft, the results indicate that the conversion itself did not affect MTBF or MMH/FH, although some time-sensitive trends did occur.

ABBREVIATIONS

ABBREVIATIONS

ACC	Air Combat Command
ADP	automatic data processing
AFB	Air Force Base
AFR	Air Force Regulation
AFRES	Air Force Reserve
AFTO	Air Force Technical Order
AGE	aerospace ground equipment
ALC	Air Logistics Center
AME	Alternate Mission Equipment
AMOC	Automated Maintenance Operations Center
ANG	Air National Guard
ATC	air traffic control
ATE	automatic test equipment
ATERS	Automatic Test Equipment Reporting System
BAQ	Basic Allowance for Quarters
BIT	built-in text
BP	budget program
CAMS	Core Automated Maintenance System
CDB	Central Data Base
CDS	Centralized Data System
CEMS	Comprehensive Engine Management System
COBOL	Common Business Oriented Language
CONUS	continental United States
CSDS	client-server data base system
CSRD	Computer System Requirements Document
DBM	data base manager
DCP	Data Communication Processor
DDN	Defense Data Network
DIREP	Difficulty Report *or* Discrepancy Report
DoD	Department of Defense
DRC	Dynamics Research Corporation

EIMSURS	Equipment Inventory, Multiple Status and Utilization Reporting Subsystem
FDWW	Functional Disconnect Work-Around Write-Up
FMC	fully mission capable
FOC	full operational capability
G&A	general and administration
GAO	General Accounting Office
GCSAS	Generic Configuration Status Accounting System
ICE	Independent Cost Estimate
ID	identification
IDA	Institute for Defense Analyses
IWSM	Integrated Weapon System Management
JCN	job-control number
JDD	Job Data Documentation
Kbps	kilobytes per second
LAN	local area network
LANTIRN	Low Altitude Navigation and Tracking Infrared System for Night
LCS	Litton Computer Services
LRU	line replaceable unit
MAISRC	Major Automated Information System Review Council
MAJCOM	Major Command
MC	mission capable
MDC	Maintenance Data Collection
MIPS	million instructions per second
MMH/FH	maintenance man-hours per flying hour
MMICS	Maintenance Management Information Control System
MOC	Maintenance Operations Center
MTBCF	mean time between critical failures
MTBF	mean time between failures
MTBMA	mean time between maintenance actions
MTBR	mean time between repairs
NATO	North Atlantic Treaty Organization
NCC	Network Control Center
NRTS	not repairable this station
O&M	operations and maintenance
O&S	operating and support
OMB	Office of Management and Budget

PACAF	Pacific Air Force
PC	personal computer
PMC	partially mission capable
PMO	Program Management Office
POE	Program Office Estimate
PPS	Product Performance Subsystem
PQDR	Product Quality Deficiency Report
QT&E	qualification testing and evaluation
QT&E	qualification testing and evaluation
R&M	reliability and maintainability
RAM	random access memory
RDA	Reportable Database Area
RECFU II	Recovered Functionality
REMIS	Reliability and Maintainability Information System
RF	radio frequency
RPC	Regional Processing Center
SBLC	Standard Base Level Computer
SBSS	Standard Base Supply System
SDS	Smart Data System
SE	support equipment
SLOC	source lines of code
SPO	System Program Office
SPQR	System Product Quality Reporting
SSC	Standard Systems Center
SSI	system-to-system input
SSO	system-to-system output
ST	self-test
TCI	time change item
TCTO	Time Compliance Technical Order
TICARRS	Tactical Interim Core Automated Maintenance System and Reliability and Maintainability Information System Reporting System
USAFE	U.S. Air Forces Europe
WAN	wide area network
WORM	write once, read many
WUC	work unit code